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ECONOMIC DEVELOPMENT OPPORTUNITIES IN NANO COMMERCIALIZATION

HEARING

BEFORE THE

SUBCOMMITTEE ON TRADE, TOURISM, AND ECONOMIC DEVELOPMENT

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED NINTH CONGRESS

SECOND SESSION

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ONE HUNDRED NINTH CONGRESS

SECOND SESSION

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WITNESSES

ECONOMIC DEVELOPMENT OPPORTUNITIES IN NANO COMMERCIALIZATION

THURSDAY, MAY 4, 2006

U.S. SENATE,
SUBCOMMITTEE ON TRADE, TOURISM, AND ECONOMIC DEVELOPMENT,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Subcommittee met, pursuant to notice, at 3:17 p.m. in room SD–562, Dirksen Senate Office Building, Hon. Gordon H. Smith, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. GORDON H. SMITH, U.S. SENATOR FROM OREGON

Senator SMITH. Ladies and gentlemen, we call to order this hearing of the Senate Commerce Committee. Thank you for your attendance, and I appreciate so much your preparation. We apologize for the voting schedule around this place. They don't check with Byron or myself when they schedule these votes. But we can go forward now.

Today's hearing will focus on economic development opportunities that exist within the field of nanotechnology; obviously, an enormously exciting field that has tremendous potential to improve the quality of life for our citizens, create high-paying jobs, and increase U.S. global competitiveness. Unfortunately, the Federal Government has not made the economic development aspect of nanotechnology much of a priority. We're going to try to do that.

This hearing is going to highlight communities and companies that are harnessing this potential and bringing jobs to their towns. Hewlett-Packard, that has a large presence in Oregon, developed the thermal inkjet technology, as one example of how advances in nanoscience and microtechnology have generated tremendous economic benefit and created high-paying jobs. It enabled the creation of this breakthrough technology, and led to tremendous growth at HP, and created numerous opportunities in our state, not only in the Corvallis area, but also for thousands of others across the country.

With the growth of nanotechnology, I envision similar types of job creation and advances in product development in the future. Today, more than 40 initiatives at the community, state, and regional levels are dedicated to nanotechnology commercialization and economic development. Advancement of nanotechnology is also evident, and quite competitive, on the global stage. Asian and European countries are making significant efforts to reap economic

benefits from commercializing this industry. Recent studies indicate that by the year 2014 nanotechnology will affect most manufactured goods and represent manufacturing output of more than $2 trillion.

At the same time, some have expressed concern regarding potential health and safety issues related to nanotechnology. These issues need to be examined as we move forward. However, we should not unfairly hinder this emerging field of science. With the potential benefits that this technology offers, the Government should do more to ensure the United States is a leader in commercializing its technology and promoting its economic benefits.

We have five witnesses here today that will discuss important issues as they relate to this topic. We thank you and look forward to hearing from you.

And I would like to especially welcome Skip Rung, President and Executive Director of the Oregon Nanoscience and Microtechnologies Institute, in Corvallis, Oregon, who's here today. We welcome you, Skip.

And, with that, let me turn to my colleague, Byron Dorgan from North Dakota.

STATEMENT OF HON. BYRON L. DORGAN,
U.S. SENATOR FROM NORTH DAKOTA

Senator DORGAN. Senator Smith, thank you very much.

First of all, let me say, I appreciate your holding this follow-up hearing. We've held one other hearing in our Subcommittee, on nanotechnology. This hearing is about partnerships and commercialization, and I think it is right on the mark, and I very much appreciate it.

I'm not able to stay for the entire hearing, because of the time problem that has occurred as a result of these votes, and I deeply apologize for that. But let me take the front end of this, just for a moment, to welcome Dr. Phil Boudjouk. At a hearing, I guess 5 or 6 years ago, in a room in this building, in a hearing room just like this, with Senator Stevens and myself, Dr. Boudjouk testified on issues, I think, dealing with EPSCoR at that moment. And, from that meeting, out in the hallway we talked about what we could, and should, do to make North Dakota State University a university that is a participant in microtechnology and nanotechnology. From that time, in the last 5 to 6 years, we have made remarkable strides, through research contracts with the Department of Defense and earmarks that I have included in legislation. The result of it all is that we now have, at North Dakota State University, a Center for Nanoscale Science and Engineering that is really quite a remarkable place. This summer, a company called Alien Technology will open the world's largest plant for making radio frequency identification tags, RFID tags, right across the street from the Center for Nanoscale Science and Engineering. A number of other high-technology companies have now located in Fargo and are participating. We think what is happening there is almost breathtaking.

We're very interested in, I'm very interested, especially, in marrying the opportunity to have Federal research join partnerships and the private sector to commercialize the kinds of things that result from all of this technology.

I think we're just in the first baby step of the development of what we will ultimately see in our lives from nanotechnology. But in order to have a destination, you've got to know where you are and where you want to be. And that's the purpose of this hearing. It's the purpose of the research that we're funding here in the Federal Government. And I just wanted to especially say that you don't have to be a New York University, Texas University, Massachusetts or California University, I mention those four, because, as you know, the huge pile of Federal dollars go to about four or five states for research, you don't have to be in one of those states to be world-class. We are creating, developing, and seeing world-class opportunities in micro- and nanotechnology applications, that exist in other areas of the country, including a world-class opportunity that is now being built and existing in Fargo, North Dakota, at North Dakota State University.

Much of the credit of that is due to Dr. Boudjouk. I'm really pleased that I was able to invite him, and that you were willing to allow him to testify today.

Senator SMITH. Of course.

Senator DORGAN. This is a great panel. I appreciate the input all of you will provide this Senate on these important issues.

And, again, Mr. Chairman, thank you very much.

Senator SMITH. Thank you, Senator Dorgan. And I agree completely with your observation. You don't have to be from one of the big ones. You can be from Oregon or North Dakota and participate in this, and maybe make the breakthroughs.

Our panel today will consist of Sean Murdock. He'll go first. He's the Executive Director of the NanoBusiness Alliance, in Skokie, Illinois; and then Robert "Skip" Rung, President and Executive Director of Oregon Nanoscience and Microtechnologies Institute, from Corvallis; and Dr. Philip Boudjouk—did I say it right?

Dr. BOUDJOUK. You did.

Senator SMITH. We welcome you, Doctor. He's the Vice President for Research, North Dakota State University, Fargo, North Dakota; and David Rejeski——

Mr. REJESKI. Rejeski.

Senator SMITH.—Rejeski—I'll get it better next time—thank you for being here, as well. He's director of Project on Emerging Nanotechnologies, Woodrow Wilson International Center for Scholars, in Washington, D.C.; and Jerry Gwaltney——

Mr. GWALTNEY. Gwaltney.

Senator SMITH. Gwaltney, OK.

Mr. GWALTNEY. Yes, sir.

Senator SMITH. City Manager, City of Danville, Virginia.

Senator DORGAN. Mr. Chairman, you could have picked some Smiths and some Olsons.

Senator SMITH. Yes.

[Laughter.]

Senator DORGAN. That's a lot easier, but these are the experts.

Senator SMITH. We're honored to be joined by the Chairman of the full Committee. Senator Stevens, we're glad you're with us, sir.

STATEMENT OF HON. TED STEVENS,
U.S. SENATOR FROM ALASKA

The CHAIRMAN. Thank you very much. I'm late but I'm happy to join you for this important hearing.

Senator SMITH. Sean, take it away.

STATEMENT OF SEAN MURDOCK, EXECUTIVE DIRECTOR,
NANOBUSINESS ALLIANCE

Mr. MURDOCK. Thank you very much.

I would like to thank you, Chairman Smith, Ranking Member Dorgan, Chairman Stevens, and the Members of this Senate Subcommittee on Trade, Tourism, and Economic Development, for the opportunity to testify on a topic of great importance to the American economy and to American competitiveness.

I would also like to thank you for introducing the Nanoscience to Commercialization Institutes Act of 2005, which we believe will help expand our Nation's nanotechnology commercialization capabilities.

My name is Sean Murdock, and I am the Executive Director of the NanoBusiness Alliance. The Alliance is the industry association policy advocate for nanotechnology innovators.

Developments in nanotechnology will boost a broad range of industry. Lux Research has predicted that nanotechnology will account for 15 percent of our global manufacturing output, totaling almost $2.6 trillion in 2014. Those figures imply an expected impact of almost 3.7 million U.S. manufacturing jobs within 10 years. And the jobs that are created are likely to be very good ones, high-paying ones. Small Times has estimated that the average annual salary for an employee in the nanotechnology sector is almost $100,000 a year.

States are making investments in nanotechnology economic development with the hope and the expectation of attracting companies and capturing these new jobs. According to Lux Research, state and local governments poured more than $400 million last year into nanotechnology research facilities, business incubation programs, and other resources, aiming to attract the further funds, the billion dollars that are being disbursed at the Federal level.

Most of the $400 million was invested in a few large-scale projects to build new buildings, and new facilities within those buildings. Only a small portion of that money is actually going to public/private partnerships that focus on connecting our research in the infrastructure to the existing businesses that may be able to use it, enhance their competitiveness, maintain existing jobs, and create new ones.

There are several key challenges for realizing economic development through nanotechnology. The first is the Valley of Death. Companies need capital and time to bring innovations to market. But VCs have been shying away from investment in early stage platform technologies without the near-term products. According to statistics from Small Times, investment in startup and seed-stage companies has dropped significantly as a percentage of total investment by over 50 percent, with startups receiving only 3 percent—early stage only 3 percent in 2005. Federal investment in basic research without adequate commercialization capital for startup com-

panies that are busy translating it into realworld applications will not result in the economic development that we expect.

Second, to truly create revolutionary groundbreaking products, often several innovations have to be realized and combined. It is often not feasible for a single company to shoulder the burden of infrastructure investment and development. Public partnerships allow all parties to align their strategies for commercialization, to leverage one another's resources, and to create the kind of roadmaps that facilitate the coordinated activity. Currently, there is no programmatic approach to foster these kind of public/private partnerships.

The third, startup nanotech companies are pioneers. They are rich in potential, courage, and ambition, but are poor in resources. As such, their ability to have a voice in policy discussions, to travel and network, and even access and apply for the Federal programs that we've put forward to help them, is extremely limited. Support for organizations that work on a grassroots level to support those startups and entrepreneurs, and act as a means for the companies to meet, share strategies, and cooperate, is essential to regional success for the industry.

We have a few recommendations. First, we strongly support the Nanoscience to Commercialization Institutes Act of 2005, sponsored by Senators Smith and Cantwell. This bill has the potential to significantly impact job growth and revenues through modest Federal investment. It achieves this by leveraging industry investments and knowhow through sets of public/private partnerships. We believe the proposed commercialization centers will encourage application-focused research, develop metrics and measurements for economic growth to ensure that we're pursuing this efficiently and effectively, inform policymakers with real data on the impact of Federal research funding so that we can make changes, going forward, and provide strategic research guidance and meaningful, achievable goals for various application areas.

We also believe that there must be more support for regional economic development initiatives. These organizations are engaged broadly in enabling efficient resource sharing, raising awareness of Federal and State programs that are already out there, so that they're better utilized and have the impact that we hope, convening stakeholders to promote cooperation not just within cities and states, but across state boundaries, and giving the industry and the entrepreneurs a voice when discussing policy at the regional, state, and national levels.

The regional economic development initiatives are grassroots industry organizations through which small businesses can have a voice and be heard and gain access to critical knowledge and resources. Given the importance of small business to innovation, providing these regional initiatives with sufficient support will be an important part of any nanotech economic development strategy.

Finally, we believe that we should enact nanotech R&D tax credits to address the Valley of Death. This would enhance the availability of early stage risk capital while leveraging market forces to decide which small businesses get the benefit. Investors will invest based on commercial potential, so these tax incentives for seed-stage investments will, through market means, encourage funding

for companies most likely to produce the jobs and revenues that we all hope and expect out of this investment.

Thank you, Mr. Chairman. I'd be happy to answer any questions.

[The prepared statement of Mr. Murdock follows:]

PREPARED STATEMENT OF SEAN MURDOCK, EXECUTIVE DIRECTOR, NANOBUSINESS ALLIANCE

I would like to thank you, Chairman Smith, Ranking Member Dorgan, and members of the Senate Subcommittee on Trade, Tourism, and Economic Development for the opportunity to testify on a topic of importance to the American economy—nanotechnology and its role in increasing our GDP, creating jobs and providing America with high-value goods to power our exports in the increasingly global economy. I also want to thank you for introducing the Nanoscience to Commercialization Institutes Act of 2005, which will help expand our Nation's nanotechnology commercialization capabilities.

My name is Sean Murdock, and I am the Executive Director of the NanoBusiness Alliance. The NanoBusiness Alliance is the nanotechnology industry association and the premier nanotechnology policy and commercialization advocacy group in the United States. NanoBusiness Alliance members span multiple stakeholder groups and traditional industrial sectors, including newly formed start-ups surviving on angel funding or government grants, Fortune 500 companies with multimillion dollar commitments to nanotechnology R&D, academic research institutions, and public-private partnerships working to derive economic development and growth through nanotechnology. This wide group of stakeholders has come together because we believe that nanotechnology will be one of the key drivers of quality-of-life improvements, economic growth and business success in the 21st century. The Alliance provides a collective voice and a vehicle for efforts to advance the benefits of nanotechnology across our economy and society.

With that perspective in mind, I would like to share with you my thoughts on the impact of nanotechnology on economic development in America.

Nanotechnology's Potential for Economic Development

Developments in nanotechnology boost a broad range of industries. Today nanotechnology is found in approximately 80 consumer products, and over 600 raw materials, intermediate components and industrial equipment items that are used by manufacturers. While the number is small at this juncture, the diversity of the products and applications—stain resistant clothing, tennis racquets, cosmetics, catalytic converters, fuel cells, solar cells, flat screen displays, molecular diagnostics and cancer therapies—provide testament to its broad impact which will deepen in the coming decade as more products come to market. Lux Research has predicted that nanotech will account for 15 percent of our global manufacturing output totaling $2.6 trillion by 2014.

The potential for economic development that nanotech represents is profound. Nanotechnology will create more jobs and better jobs over the next decade. According to Lux estimates, the number of jobs in making nano-enabled products is set to balloon from 47,000 globally today to more than 10 million in 2014—11 percent of total manufacturing jobs in that year. Of these, the U.S. should capture at least 37 percent or 3.7 million. And, studies show that on a national level, nanotechnology employees today have higher than average salaries and are highly educated. In the United States, the average annual salary for an employee in the nanotechnology sector is $97,978.

The State of Nanotechnology Commercialization in the U.S.

According to the NanoBusiness Alliance's proprietary database on all companies involved with nanotechnology worldwide, a little over 50 percent of the companies are in the United States. However, if one is to believe the announcements made at the ChinaNano2005 trade expo that China has almost 800 companies involved with nanotechnology and a recent EU report claiming that Europe has 500, the share would appear to be significantly lower. Unfortunately, it is notoriously difficult to track commercial developments in nanotechnology, so we cannot be precisely sure.

Regardless of the international situation, the growth of new, venture backed nanotech start-ups has been relatively stagnant over the past few years. This is, perhaps, one of the most disconcerting indicators for nanotechnology in the U.S. The entrepreneurial culture and deployment of risk capital, especially venture capital, toward early stage technology companies has been a key source of competitive advantage for the United States.

States are making investments with the hope and expectation of attracting nanotechnology companies and capturing these new nanotech jobs. According to Lux Research, state and local governments poured more than $400 million last year into nanotechnology research, facilities, and business incubation programs, aiming to attract further funds from the nearly $1 billion being disbursed at the Federal level.

Most of the $400 million was invested in a very few, large projects to build new research facilities and buildings to house those facilities. Albany Nanotech in NY, The International Institute for Nanotechnology in Illinois, and The California Nanosystems Institute are good examples.

Little money is actually going to public-private partnerships that focus on connecting those performing our federally funded research to the existing businesses that may be able to use that technology and make use of the new facilities and infrastructure that have been created.

Barriers to Nanotech Commercialization in America

The following outlines some of the most prominent barriers to commercialization.

The Valley of Death

The trying period between a company's formation and its achieving significant cashflow, referred to as the "valley of death," is particularly acute for nanotechnology. Lab research holds the potential to develop game-changing products but requires a significant investment in process knowledge and internal capabilities before any revenues can be generated. This investment is required to identify a particular product need, integrate the lab process with current manufacturing techniques, develop the lab process so that efficient large-scale production is possible, handle compliance with any regulatory statutes, and also fund the operational infrastructure of the company.

Burned by the dot com bubble and needing to raise IRR's in order to raise the next fund, VC's have been shying away from early stage technologies without near term commercialization processes and end market economics. According to statistics from Small Times, investment in startup and seed-stage companies has dropped as a percentage of total investment, by 50 percent (with startups receiving only 3 percent in 2005). *Federal investment in basic research without adequate capital support for the startup companies that translate it into real world applications will not result in economic development.*

Lack of a Level International Playing Field for American Companies

On a per capita basis and relative to GDP, the U.S. funding of nanotech innovation and commercialization is matched or exceeded by its Asian competitors (particularly Japan and Korea). Also, Asian investments tend to be more focused on specific applications. While these competitors are not outperforming the U.S. in knowledge development (*i.e.,* overall patents), they are developing leadership in specific areas, particularly electronics related applications. Foreign governments (particularly in Asia) also provide direct subsidies for application development which creates an un-level playing field for American nanotech startups.

The U.S. Government must be the "gold standard" as the most hospitable climate for commercializing nanotech innovations. We must lead in the development of new nanotech knowledge and research infrastructure. *As such, our share of worldwide government investment should be at least on par with our share of global GDP.*

Insufficient Opportunities for Public-Private Partnerships

Turning the ideas and innovations being funded into manufactured products is the key to the government seeing a return on its investment in research. However, to create a truly revolutionary or ground-breaking product, often several innovations have to be realized and combined. For example, developing a successful nanomaterial requires advances in measurement and metrology, materials engineering, product integration and manufacturing process. This requires an extensive research infrastructure with multiple areas of specialization. It is not feasible for a single company to shoulder the burden of infrastructure investment and development.

Public-private partnerships allow both parties to align their strategies for commercialization, leverage each others resources and help create fundamental roadmaps for economic growth and development. Currently, there are no institutions that foster or house these partnerships.

Lack of Support for Regional Economic Initiatives

Startup nanotech companies are pioneers—rich in potential, courage and ambition but poor in resources. As such, their ability to have a voice in policy discussions, to travel and network and even to access and apply for Federal programs and support is extremely limited. Support for organizations that work on a grassroots level

and act as a means for these companies to meet, share strategies and cooperate is essential to regional successes in this industry.

Recommendations and Proposals

Create Commercialization Centers to Promote Public-Private Partnerships

We recommend creating centers for nanotech commercialization that allow public and private stakeholders to share the costs of developing infrastructure for conducting fundamental, application-focused nanotechnology research. We strongly support the Nanoscience to Commercialization Act of 2005 (S. 1908), sponsored by Senators Smith and Cantwell. This bill has the potential to significantly impact job growth and revenues through a modest Federal investment. It achieves this by leveraging industry investments and know-how through a set of public-private partnerships.

The proposed commercialization centers would:

- Encourage application-focused research.
- Developing metrics and measurements for economic growth in the industry and publishing analyses of American competitiveness in this space.
- Informing policymakers with real data on the impact of Federal research funding in nanotech on job growth and revenues.
- Provide strategic research guidance and meaningful, achievable goals and challenges for various application areas.

The centers could act as the focal point for industry to develop roadmaps for multi-component applications. This would help small businesses that have innovations for one or more components to focus their development and collaborate to create the larger application.

In addition, the data being generated at these centers can streamline Federal research investments so that dollars are being spent to achieve a maximum return. It can also draw on regional initiatives to develop effective and relevant strategies for dealing with commercialization challenges. Finally, by focusing on areas that do not already have nanotechnology centers, the bill promotes an expansion of the Nation's nanotechnology infrastructure.

Providing Funding for Regional Economic Initiatives

Regional economic initiatives are engaged, broadly, in the following missions:

- Developing nanotech clusters to allow resource sharing.
- Raising awareness of Federal and state programs and infrastructure available to startups.
- Convening conferences to promote cooperation across geographies.
- Giving the nanotech industry a voice when discussing policy at the regional, state and national levels.

There are over 40 nanotech initiatives throughout the U.S. dedicated to developing tactical plans to realize the strategy above. To date, two workshops have been held by the NNCO to facilitation coordination across these initiatives. The main focus of these workshops has been to compare strategies for acquiring funding and models for building working nanotech clusters in the various regions. The product has been the development of some "best practices" and a series of recommendations on how to structure an initiative and best utilize the scarce resources.

The regional economic initiatives are the grassroots industry organizations through which small businesses can have a voice and be heard. Given the importance of small business to innovation, providing these regional initiatives with sufficient support must be an important part of any nanotech economic development strategy.

Provide a Tax Incentive for Investment in Small Business

A recommendation for addressing the "valley of death" and the un-level playing field is to develop tax incentives for investors in small businesses engaged in translating research from labs into applications and products.

The R&D Tax Credit in section 41 of the Tax Code is, of course, an important incentive. However, it does not benefit many small nanotechnology companies, because they do not have profits and thus do not have taxes against which the credit can apply. Furthermore, our experience is that investors do not factor the future availability of credit "carry-forwards" into account, especially for small companies. Thus, many small nanotechnology companies will fail from a lack of capital before the credits are available.

States have successfully used tax credits to dissuade nanotech companies from migrating to other states (*e.g.,* in Wisconsin). The same can be accomplished on a national level, thereby preventing off-shoring of nanotech development. In addition, this approach would rely on market forces to decide which small businesses get the benefit; in other words, investors still will invest based on which nanotech companies have the highest potential for commercialization (and other business-driven factors). As a result, tax incentives for seed-stage investments will, through market means, encourage funding for companies most likely to produce jobs and revenues.

Thank you Mr. Chairman. I would be happy to answer any questions.

Senator SMITH. Sean, I'm curious, and I would like to ask a question. What I'd like to do, if it's all right with my colleagues, is, as each one gives his testimony, if you have questions, we'll just take them up right then and have a fuller free exchange.

The CHAIRMAN. How long are you going to take on each one of us on that first round?

Senator SMITH. Not long at all.

The CHAIRMAN. OK.

Senator SMITH. Sean, how is America relative to our competitors in nanotechnology commercialization? Where do we stand?

Mr. MURDOCK. We have about half of the nanotechnology startup companies, if you will, located in the United States.

Senator SMITH. And where are the others located?

Mr. MURDOCK. They are distributed across the entire globe—in Europe, and concentrated heavily in Asia, in Japan, in China. If you are to believe some of the statements that have been made by the Chinese, we don't have the majority of the companies. There was a statement made at one of their trade shows that they have 800 companies working on nanotechnology commercialization. We have no way of verifying that. But that would put them in the lead, if it was, in fact, true.

Senator SMITH. Do you have a question for him?

STATEMENT OF HON. GEORGE ALLEN, U.S. SENATOR FROM VIRGINIA

Senator ALLEN. Let me just add something to Mr. Murdock's statement. Your colleague, from Oregon, and I have been leaders in the Senate working with our colleagues here, on nanotechnology, and making sure the United States is a leader in it. And there's been over a billion dollars in funding. A lot of it's now getting focused in energy and other areas. In China—you mentioned China—we do need to stay in the lead; otherwise, European or Asian countries will be in the lead.

In the applications in a round-the-world trip that brought us to India and also to China, I looked at China nanotechnology, because I was interested in this very question you asked. Nanotechnology can be everything from life sciences to energy to materials engineering to electronics. China seems to be focused mostly in the materials engineering, and they seem to—and if you want an analogy, they're like—and I know you like baseball—they're like George Steinbrenner. They will pay what it takes to get the best engineer in materials engineering and engineers who understand the carbon nanotubes, which are part of materials engineering. And they are a directed economy, and they are focused, and they want to take the lead in that aspect of it, in the materials, which are lighter and stronger nanomaterials, as opposed to some of the life sciences or

health sciences aspects of nanotechnology. So, we need to be in the lead.

Senator SMITH. Yes.

Senator ALLEN. And whether it's research through Federal agencies, colleges, universities, the private sector, and the states, which is part of what your bill aims to do, I think that's a very important component of it, and recognize our competition, if we didn't move, would actually be gaining ground, and, in fact, surpassing us over a period of time.

Senator SMITH. And in those various areas that Senator Allen named, Sean, are we in the lead or behind in any of those, or are we leading in some, and not in others?

Mr. MURDOCK. We have a very strong foundation in the basic research across the board. We have good leadership there. We haven't been—you asked the question about the translation of that into products, and there, we're not as strong. We do well in the biomedical arena, healthcare arena, because we have such a strong biotech industry here. In the electronics arena, we're already finding that many of the nanotech startups have applications relevant to electronics are having to go over to Asia to find their partners and to partner to commercialize the technologies there.

Senator SMITH. Senator Stevens?

The CHAIRMAN. I have two short, but sort of stupid questions. Is your headquarters in Illinois?

Mr. MURDOCK. Yes, it is.

The CHAIRMAN. How did that happen? I mean, that's not a normal place for a national center, is what I'm saying.

Mr. MURDOCK. Well, it happened from a few things. One, I'm based in Illinois, and I have been for a while. I grew up in the Chicagoland area, but also——

The CHAIRMAN. Did you name yourself the "Center," or do you really have a lot of members?

Mr. MURDOCK. No, there's a lot that—well, the Alliance is a national organization, so we have members around the country. But there is quite a bit of capability in the Chicagoland area—Argonne, Northwestern——

The CHAIRMAN. My not-so-stupid question is—we're working in this Committee to try and deal with the problem outlined by the report "Rising Above the Gathering Storm" that shows us that there is a decline in the production of graduate students in science, technology, and engineering. Having this separate nano division now, is that producing a competition within the numbers we are projecting? I mean, after all, it looks like China and India are producing about 1.1 million engineers while we're producing 70,000. That doesn't sound like there are a lot of engineers who work on nanotechnology. Are we splitting our forces too much?

Mr. MURDOCK. Well, I think that having the focus on nanotechnology is actually quite powerful. As we talk about some of these grand challenges of clean renewable energy or high-powered computing, et cetera, it serves to motivate the children and the younger students to think about how this will tangibly affect their world. And at least from the people I've interacted with at the grade school and the high school levels, it's getting excitement where they're going to consider going into the engineering disciplines. But

I think we need to have not just a—what I would characterize as a "push" strategy, which is throw more money about it in the educational infrastructure, but a "pull" strategy, where they start to see that there are going to be good, high-paying, dynamic, fun, exciting jobs that will change the world through the commercialization of nanotechnology, and then we will get more people going into the engineering disciplines. I think we have to do both.

The CHAIRMAN. Did you participate in the Augustine study and report?

Mr. MURDOCK. No, I did not.

Senator SMITH. Senator Dorgan's schedule is going to have him leaving earlier than the conclusion of this hearing, so, in the interest of his time, we'll go to Dr. Boudjouk, and then we'll go back to Skip Rung.

STATEMENT OF PHILIP BOUDJOUK, PH.D., VICE PRESIDENT OF RESEARCH, NORTH DAKOTA STATE UNIVERSITY

Dr. BOUDJOUK. Thank you.

Chairman Smith, Ranking Member Dorgan, and members of the Committee, thank you for the opportunity to discuss the importance of helping to commercialize discoveries nanotechnology and some of the critical roles that universities could play.

There's a big future in small things, and the consequences for our economy can be enormously positive if we harness the potential of nanotechnology. By "harness," I don't mean probing the depths of understanding of what nature is telling us when we "go nano." I mean "harness" in the sense of developing and commercializing technologies that will find places in the market because they meet the needs of our citizens.

Enhancing our understanding comes from our efforts in science. Implementation, and, therefore, economic development, however, derives from advancing technology. There will always be important questions for science to answer about nanomaterials, and, just as important, about energy on the nanoscale; for example, devices using only nanowatts of energy. But I wish to emphasize that we know enough now that we can move forward today to the marketplace by pushing the nanotechnology envelope.

This is the time to forge the links to our economy. This can be done by providing incentives for efficient pipelines, from science to technology to economic development. For the topic today, the focus would be nanoscience to nanotechnology, but—and here comes the good part—to macroeconomic development. The economic development payoff could be enormous.

In North Dakota, we have made important progress in converting nanotechnology into economic development. Thanks to the vision and support of Senator Dorgan, we have been able to forge partnerships with the private and Federal sectors to develop microdevices that operate at the nanowatt level. These devices have the critical advantage of emitting virtually undetectable signals, a property very important in matters of national defense and security.

While our original work was focused on meeting the needs of the Department of Defense, our partnerships with the private sector have led to sophisticated, yet practical, joint efforts to address commercial needs and markets. The value of the partnerships in incal-

culable, because now the considerable intellectual capital and remarkable technical infrastructure put in place at North Dakota State University to address Federal needs has been, and will continue to be, targeted to the commercial sector. And targeting is what we universities need.

Universities are generally not savvy to the marketplace. Never have been, likely never will be. It has the partnership with the private sector that enables the efficient leveraging of our tremendous resources. We universities—not all of us, perhaps, and probably not all aspects of a university, but surely parts of many universities, should be tuned to the markets. And that tuning would best be done in collaboration with our partners in the private sector. This is a win-win on a grand scale.

For us, in Fargo, North Dakota, an area not previously known for high-technology-based industries, we now have Microsoft Great Plains, John Deere, Ingersoll Rand, and, this month, Alien Technology, the world leader in radio frequency identification technology will open its doors in the North Dakota State University Research and Technology Park. They are in Fargo because Senator Dorgan challenged us to form a three-part partnership—Federal, State, and private—and North Dakota has. Our Governor, our legislators, and our State Board of Higher Education have provided the necessary local leadership and support to make great things happen. The rewards have been enormous. The Senator's vision has led to the Red River Valley Research Corridor, anchored by our two research universities, North Dakota State University and our sister institution, the University of North Dakota, forming one of the most powerful marketing tools in the Upper Midwest, and the birthplace of the high-technology sector in that region.

The NDSU Research and Technology Park is a remarkable achievement for the community, the state, and the region. What was once 55 acres of sunflower test plots is—now supports 250,000 square feet of research and development space where 400 people come to work every day in high-technology industries. Next year, that will be 300,000 square feet and 600 people. Seventy-five percent of those people were not in North Dakota 5 years ago. The average salary is more than double that average—the average in Fargo.

We now have, as a result of these partnerships with the private sector, nanotechnologies that I am confident will be commercial products within 3 years. Some examples are nanostructured coatings to inhibit corrosion on aircraft; nanostructured coatings to reduce fouling on ships and enhance their fuel efficiency and improve maneuverability; nanowatt-level devices for sensors, detecting toxic materials, specific radio frequencies and emissions, changes in temperatures in magnetic fields; nanowatt technologies for tracking livestock and other elements of our food supply.

We have had great success in this area, and I'm delighted to answer questions. But first, let me thank you for this opportunity. I'm gratified that your Committee is addressing these issues. And I am honored to have had the opportunity to offer my comments.

Thank you.

[The prepared statement of Dr. Boudjouk follows:]

PREPARED STATEMENT OF PHILIP BOUDJOUK, PH.D., VICE PRESIDENT OF RESEARCH, NORTH DAKOTA STATE UNIVERSITY

Chairman Smith, Ranking Member Dorgan and Members of the Committee:

Thank you for the opportunity to discuss with you today the importance of helping to commercialize discoveries in nanotechnology and some of the critical roles that universities could play.

There is a big future in small things and the consequences for our economy can be enormously positive if we can harness the potential of nanotechnology. By harness, I do not mean probing the depths of understanding of what Nature is telling us when we "go nano." I mean harness in the sense of developing and commercializing technologies that will find places in the market because they meet peoples' needs.

Enhancing our understanding comes from our prodigious efforts in science. Implementation, and therefore economic development, however, derives from *advancing technology*. There will always be important questions for science to answer about nanomaterials, and, just as important, about energy on the nanoscale, e.g., devices using only nanowatts of energy. But, I wish to emphasize that we know enough now that we can move forward, today, to the marketplace by pushing the nanotechnology envelope.

This is the time to forge the links to our economy. This can be done by providing incentives for efficient pipelines from science to technology to economic development. For the topic today, the focus would be: NANOscience to NANOtechnology but, and here is the good part, to MACROeconomic development. The economic development payoff could be enormous.

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While our original work was focused on meeting the needs of the Department of Defense, our partnerships with the private sector have led to sophisticated, yet practical, joint efforts to address commercial needs and markets. The value of the partnerships is incalculable because now, the considerable intellectual capital and remarkable technical infrastructure put in place at North Dakota State University to address Federal needs has been and will continue to be targeted to the commercial sector. And targeting is what we universities need.

Universities are generally not savvy to the marketplace; never have been, and likely never will be. It is the partnership with the private sector that enables the efficient leveraging of our considerable resources. We universities, not all of us perhaps, and probably not all aspects of a university, but surely parts of many universities, should be tuned to the markets. And that tuning would best be done in collaboration with our partners in the private sector.

This is a win-win on a grand scale. For us, in Fargo, North Dakota, an area not previously known for high technology-based industries, we now have Microsoft Great Plains, John Deere, Ingersoll Rand and, this month, Alien Technology, the world leader in Radio Frequency IDentification technology will open its doors in the North Dakota State University Research and Technology Park. They are in Fargo because Senator Dorgan challenged us to form a three part relationship: Federal, State, and private. And North Dakota has. Our Governor, our legislators and our State Board of Higher Education have provided the necessary local leadership and support to make great things happen. The rewards have been enormous. The Senator's vision has led to the Red River Valley Research Corridor, anchored by our two research universities, NDSU, and our sister institution, the University of North Dakota, forming one of the most powerful marketing tools in the Upper Midwest, and the birthplace of the high technology sector in that region.

The NDSU Research and Technology Park is a remarkable achievement for the community, the state and the region: what was once 55 acres of sunflower test plots in the northwest corner of our campus 6 years ago now supports over 250,000 square feet of research and development space where 400 people come to work every day in high technology industries. By this time next year the numbers will be more than 300,000 square feet and 600 employees. Seventy-five percent of those people were not in North Dakota 5 years ago. The average salary is more than double the average wage in Fargo.

We now have, as a result of these partnerships with the private sector, nanotechnologies that, I am confident, will be commercial products within 3 years. Some examples are:

1. Nanostructured coatings to inhibit corrosion on aircraft;

2. Nanostructured coatings to reduce fouling on ships that will greatly enhance their fuel efficiency and improve maneuverability;

3. Nanowatt level devices for sensing toxic materials, specific radio emissions and changes in temperature and magnetic fields as well as for item tracking and for displays; and

4. Nanowatt level technologies for tracking livestock and other elements of our food supply.

We are presently working with companies to develop nano-based products to improve lifetimes of body replacement parts, increase complexity of the smallest electronic components available today and increase the production of nanomaterials as feedstocks for industry. The key here is that our focus is the market and we are getting the right kind of guidance. Any efforts to better connect the universities to the market will be greatly rewarded in terms of enhanced economic development.

The pipeline from science and technology on our campuses to product development and commercialization has to be put in place wherever we can. The critical step is the forging of links between campus developed nanotechnologies to the private sector. This is no time for gaps. We all know that we are in a global competitive environment and markets move quickly. Missing a product cycle is damaging to every company but it can be fatal for a small enterprise.

I am gratified that your Committee is addressing these issues and I am honored to have had this opportunity to offer my comments.

Thank you.

Senator SMITH. Well, thank you, Doctor. Obviously, you're setting a very good example for the rest of the country in how you commercialize this.

Senator Dorgan, do you have a question?

Senator DORGAN. First of all, thanks to Dr. Boudjouk for the leadership.

On the issue of RFID technology, the radio frequency identification tags, it's going to be a big part of our future, and we are poised to play a significant role in that. I understand that the chips, for example, that will be produced by Alien Technology are microtechnology. They are defined as microtechnology. But the energy used to power them is nanotechnology. Can you explain that, number one? And, number two, how far away are we from commercializing the research that is done on nanotechnology as it relates to energy on a larger scale?

Dr. BOUDJOUK. The chips are, indeed, very small, require very little bits of energy. And if the demand on them—you can have a variety of demands on those chips—if the demand is in the form of just item tracking, let us say, as an elegant barcode, then you're going to need less information—less energy than if you're involved in the sensing mode, where you really want to process lots of information. But most importantly is that you would only query these chips periodically and rarely. And most of the time they would go into a mode still alive where they are emitting a barely or undetectable amount of energy. And so, whereas we've seen, even with computers in a sleep mode, they are warm and they stay warm, and they eventually generate quite a bit of heat, that type of technology reduces that to a very small level.

In terms of the second question, Senator, the products are in the market now. Alien Technology will be making, in the year beginning, I'd say, this September, 10 to 20 billion radio frequency identification tags for the market.

Senator DORGAN. Thank you.

Senator ALLEN. Say that again. Could you repeat that?

Dr. BOUDJOUK. That would be "b," as in——

Senator ALLEN. The whole sentence again.

Dr. BOUDJOUK. Within a year, beginning in September 2006, Alien Technology will be producing, in Fargo, North Dakota, 10 to 20 billion—"b," as in "burger"—billion chips for devices to be used in the market. So, we're there.

Senator SMITH. You're not burgling anything, though. You're selling it.

[Laughter.]

Senator SMITH. Senator Stevens, do you have any questions for this witness?

Senator Allen, do you have any?

Senator ALLEN. I would just commend you all, there at North Dakota State. This is an example that I would like to see. I'm glad we have the economic developer, city manager of Danville, but this is what I think that all of us would like to see, particularly the convergence of university research, the private sector, and the application. And I can tell by your accent it's not the usual, "You ot-ta go to North Da-ko-ta" accent.

And so—and the other thing—Mr. Chairman, I know we care about enticing more young people into the areas of technology, and technology jobs pay, on average, for the whole country, about 85 percent, or nearly double, average wages. And here we are—just 2 days ago, Senator Cornyn and I and a few others introduced a bill to get H1B visas increased, to get more people in from other countries. There's a tremendous demand for technology workers in this country. And I'm for these H1B visas. In fact, we ought to attach a visa to any graduate—I don't care if they're from India or France or wherever they're from—if they get a degree in one of these fields. But it—there's tremendous demand, and we need to get more young people, women, African Americans, and Latinos, in particular, that are disproportionally low in the number of scientists, engineers, and technologists in this country. And if you can do it at North Dakota State, you've set a model for this country. And congratulations. And I commend you and the vision of Senator Dorgan, your legislators, and your Governor, as well.

Senator DORGAN. Senator Allen, I might just point out, he is an import, but he's been there many, many years, and he wasn't much until he got there.

[Laughter.]

Senator DORGAN. And now he's world class.

[Laughter.]

Senator DORGAN. And what he's building is world class. And we're enormously proud of Dr. Boudjouk.

Dr. BOUDJOUK. Senator, thank you.

Senator SMITH. Thank you very much, Dr. Boudjouk.

We'll now turn to an Oregonian. Skip Rung, tell us about your great center.

STATEMENT OF ROBERT D. "SKIP" RUNG, PRESIDENT/ EXECUTIVE DIRECTOR, OREGON NANOSCIENCE AND MICROTECHNOLOGIES INSTITUTE (ONAMI)

Mr. RUNG. Chairman Smith, Ranking Member Dorgan, Chairman Stevens, and members of the Committee, thank you for the

opportunity to speak with you today, and thank you, Senator Smith, for taking leadership to introduce Senate bill 1908.

My name is Skip Rung, and I am the President and Executive Director of Oregon Nanoscience and Microtechnologies Institute, which is the State of Oregon's first signature research center, and, as such, a deep collaboration among industry, investors, government agencies, and research institutions, including the Pacific Northwest National Laboratory in the State of Washington.

Our theme, nanoscience combined with microtechnologies, was selected because it was the optimum overlap of research excellence, high-wage job-creation potential, and our existing industry strength. Indeed, although Oregon is a small state, we have the third largest semiconductor workforce, and, even more important than that, we have the world's top industrial research and development assets in the fields of nanotechnology and microtechnology. Intel Corporation and Hewlett-Packard both have their most advanced operations in the State of Oregon, and FEI company is one of our homegrown successes; FEI, of course, being the world leader in tools for nanotechnology. So, Oregon is both a high-tech and a manufacturing leader, and our future prosperity and supply of high-wage jobs requires that we remain so.

Prior to ONAMI, I worked, for 25 years, at Hewlett-Packard, most recently as the RD director for HP's world-leading thermal inkjet technology, which ranks among the most successful nanoscience and microtechnology innovations of all time. Overcoming many daunting challenges, this breakthrough technology took back the PC printer business from the Far East and created thousands of high-wage jobs across the United States. HP's Corvallis, Oregon site grew from 3 buildings to 11 large buildings in the space of 8 years, and we were always hard pressed to keep up with customer demand and to stay ahead of the competition. But the only downside to this story is that no one innovation keeps giving forever. We knew that the inkjet business would mature approximately in 2005, and we worried that our site and community were both at risk without a robust diversification plan. So, it was in 1997 that we began to take a much greater interest in new business creation, using both internal efforts and working with the universities in our region.

I wish, frankly, that we had started sooner, because it may be that no single opportunity will be as large as inkjet. And, indeed, there is lower employment in Corvallis right now in manufacturing than there was at the peak of inkjet development.

In the news recently, we have read that the personal computer market is also maturing and that this is driving reinvention discussions in other technology powerhouse companies such as Intel Corporation. The common theme, again here, is that innovation, by its very nature, means reinvention, and success or failure at this reinvention is going to have dramatic impact on employment levels, wage levels, and community health across the country.

Now, my reason for going through all of this is to introduce five conclusions I have reached after many years of thought regarding innovation, nanotechnology, and economic development.

The first is that traded-sector competitiveness is the key to high relative productivity, which, in turn, is the only dependable basis

for the high-wage jobs and prosperity Americans have come to expect.

The second is that innovation, in the form of trained people and protected intellectual property, is the key to competitiveness. Head-to-head global competition in traded-goods manufacture simply cannot deliver the wage differentials we want. Being 20 percent more efficient will not enable us to pay 20 times higher wages.

The third point is that continued leadership in prosperity based on innovation carries a price tag of constant change, sacrificial investment, hard work, and, frankly, a fair amount of stress. If emerging global competitors embrace future opportunities with greater focus, defer more gratification to prepare their citizens, and simply work harder, I fear it will go very hard with us and with our children.

The fourth conclusion is that "nanotechnology," which in somewhat oversimplified terms means the current state of progress in the physical sciences, is the frontier, the battlefront in the global innovation competition. We will keep, or lose, our prosperity, and all that comes with it, based on the outcome of this one global competition.

The fifth conclusion is that we must find a way to get the most out of our fabulous national assets: the world's best universities, the world's best system of entrepreneurship and new-venture financing, superior industrial research and manufacturing sites, and outstanding Federal laboratory and science agency capabilities. So, specifically, I mean that we need not only to invest in research and education as if they were our future, which they are, but also to accelerate the commercialization of innovation by funding and measuring this specific outcome, and removing the barriers to more powerful and effective collaboration between businesses and research institutions.

So, with these concerns always in mind, I have been encouraged, this year, by both the President's American Competitiveness Initiative and Senate bill 1908 under consideration by this Committee. By taking a hard look at where growth in high-wage jobs is most likely to be found and ensuring intimate involvement by industry and investment professionals in all aspects, the probability of success will be maximized.

ONAMI is, itself, a bold experiment for the State of Oregon in this direction, and we look forward to working with you on this vitally important mission.

In my written testimony, I have included some comments from our board chair, Dave Chen; Jay Linquist, our commercialization manager; and myself, regarding detailed implementation of Senate bill 1908. We'd be happy to discuss that and answer any other questions.

Thank you.

[The prepared statement of Mr. Rung follows:]

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The second is that innovation—in the form of trained people and protected intellectual property—is the key to competitiveness. Head-to-head global competition in traded goods manufacture simply cannot deliver the wage differentials we want. Being 20 percent more efficient will not enable us to pay 20x higher wages.

The third is that continued leadership in prosperity based on innovation carries a price tag of constant change, sacrificial investment, hard work, and—frankly—a fair amount of stress. If emerging global competitors embrace future opportunities with greater focus, defer more gratification to prepare their citizens, and simply work harder, I fear it could go very hard with us and our children.

The fourth is that nanotechnology—which in somewhat over-simple terms means the current state of progress in the physical sciences—is the frontier, the battlefront, in the global innovation competition. We will keep or lose our prosperity—and all that comes with it—based on the outcome of this one global competition.

The fifth is that we must find a way to get the most out of our fabulous national assets—the world's best universities, the world's best system of entrepreneurship and new venture financing, superior industrial research and manufacturing sites, and outstanding Federal laboratory and science agency capabilities. Specifically, I mean that we need not only to invest in research and education as if they were our future—which they are, but also to accelerate the commercialization of innovation by funding and measuring this specific outcome, and removing the barriers to more powerful and effective collaboration between businesses and research institutions.

With these concerns always in mind, I have been encouraged of late by both the President's American Competitiveness Initiative and Senate bill 1908 under consideration by this Committee. By taking a hard look at where growth in high-wage jobs is most likely to be found, and ensuring intimate involvement by industry and investment professionals in all aspects, the probability of success will be maximized. ONAMI is itself a bold experiment for the State of Oregon in this direction, and we look forward to working with you on this vitally important mission.

ATTACHMENT—THE NEED FOR NANOSCIENCE TO COMMERCIALIZATION CENTERS AND COMMENTS ON IMPLEMENTATION OF S. 1908

John M. Lindquist, ONAMI Commercialization Manager; David Y. Chen, ONAMI Board Chair; and Robert D. "Skip" Rung, ONAMI President and Executive Director.

The promise and potential benefits of nanotechnology are real. The Federal Government is wise to consider taking explicit steps to lead, enable and accelerate the commercialization of technologies stemming from its investment in nanotechnology research. S. 1908, Nanoscience to Commercialization Institutes, if implemented wisely, will yield dramatic economic benefits at the national, regional and community levels and help to ensure U.S. competitiveness for years to come.

Nanotechnology is the ultimate frontier (atomic scale) for materials science and device fabrication, and will initiate the next generation of technology-driven economic development for the U.S. It is appropriate that the Federal Government has invested or authorized billions of dollars for basic nanotechnology research. Findings from this research will enable life-saving medicines, secure and sustainable energy supplies, ultra-fast computers, communication devices for both consumer and national security efforts, wear-resistant clothing and battle gear, and dramatic improvements in environmental quality.

It is important to understand, though, that scientific research and technology development do not directly lead to commercialization and its associated economic and social benefits. The tremendous potential advancements brought about by Federal research dollars are at risk of lying fallow due to lack of commercialization efforts to bring them from the laboratory to technology proof-of-concept, and from proven technology to user-tested products which can profitably be taken to market. The Federal Government can take the lead in driving commercialization of nanotechnology research with the establishment of Nanoscience to Commercialization Centers at key locations throughout the country, each focused on a key area of commercialization and leveraging the vast array of regional capabilities, both industrial and academic, present in each area.

For example, Oregon's decision to focus on three aspects of nanotechnology—nanolaminates and transparent/printed electronics, green nanomanufacturing, and nanoscale metrology—was made in large part because of the world-class industrial R&D and manufacturing assets (*e.g.,* at HP, FEI, Intel, LSI Logic/Nantero, Electro Scientific Industries, TriQuint, Xerox. etc. . . .) we could hope to leverage.

S. 1908, Nanoscience to Commercialization Institutes can provide the key elements associated with successful commercialization of nanotechnology research: leadership, early stage funding to bring technologies out of the lab and into the market, and development of an infrastructure, culture and network to enable, support and effectively catalyze technology commercialization.

- *Leadership* will bring focus, drive, and strategic planning to this process and we believe each Center must be held accountable to strict metrics and push commercialization through critical business planning processes.
- *Funds* will be necessary to establish the Centers, staff them with talented and experienced business professionals, and protect the intellectual property generated by Federal research dollars.
- *Incentives* are needed to encourage entrepreneurs to develop product prototypes. We believe the use of Federal and state tax credits (as Oregon has begun to do) will be an important tool to bring investors into this high-risk phase of the commercialization process.
- *Development of an infrastructure* which supports commercialization at the regional level will leverage existing facilities, tools, and human capital which can provide the critical mass of capabilities to support this process.

We have two final observations which we think may be helpful as detailed planning for Nanoscience to Commercialization centers begins:

1. Even at a time of global networks and instant communications, nanotechnology commercialization actually calls for *localization.* The centerpieces of this localization will be shared physical facilities within easy commuting distance of both researchers (university faculty and graduate students, national laboratory technical staff) and industrial product development personnel. These facilities are expensive both to build and maintain. A critical-mass local community which includes research institutions, industry, entrepreneurs and sophisticated investors is needed for such facilities to be truly successful.

2. Judicious selection of a *practical application theme* (and perhaps also a "grand challenge") that is not too broad and not too narrow can be a vital catalyst for a commercialization community. Combining the "DARPA approach" to problem solving (define an important challenge, invite experts to a brainstorming workshop, issue a funding solicitation, fund the best ideas, down-select the best performers for development) with dedicated facilities and co-located expertise as described above may be the optimum model to consider.

In conclusion, we believe S. 1908 centers implemented along the above lines will be *hubs* for networking regional assets and *magnets* for technology commercialization. They will yield a cluster of critical technologies, investment funds, human and capital assets, and the essential leadership required to accelerate the process. Regional economies will grow around these commercialization centers as a workforce, set of suppliers and service providers are attracted to the companies which emerge from each Center.

Senator SMITH. Skip, when I first came to the Senate, the dot-com business was booming, the Silicon Forest was the answer to the old forest. We didn't need to cut trees or any of those old kinds of jobs. But I always remember hearing, as I learned more about this new sector of the Oregon economy, that when high-tech companies hit the wall, there were no skidmarks.

Now, when we saw the dot-com bubble burst, it seemed like there were a lot of wrecks around, and not many skidmarks. But I think what you're telling me is, ONAMI and Hewlett-Packard and Intel and others actually are planning and targeting out the life of their products. I'm sure you'll tell me that they fully comprehend where nanotechnology fits into future products. There's a market incentive out there to bring from the laboratory to the shelves of our businesses these new products.

Mr. RUNG. That is quite true. Intel and Hewlett-Packard, which have, as I said, their most important operations in the whole world in Oregon, have followed a very similar model for manufacturing jobs, and that is that you perform advanced research in the next generation of technology—the Pentium 5 processor or the fourth-generation thermal inkjet—you make a massive investment in tooling and equipment and facilities and people to do the final stages of development, the early manufacturing, perhaps, for 1 or 2 years, and then, as that business takes off, you expand at hub sites—Intel calls this "copy exactly"; at HP, we called these "regional hub sites"—and then, in the space left behind, you invent the next generation.

So, what the American very-high-cost locations are involved in doing is mostly product development, and that's how you have the high-wage jobs, is that the old generation becomes old, it becomes a commodity, but you're there with the next one. And so, indeed, that's where nanotechnology fits in for companies like Intel and HP and FEI.

Senator SMITH. Yes. Now, for my colleagues, I know how ONAMI came together. We see, on a regular basis, the great universities compete quite vigorously for grants out of this place, but it seems that what you did was, instead of competing with all the regional universities, you got together one organization to pool these things. And could you describe that for my colleagues and for the Senate record?

Mr. RUNG. So, Oregon is a small State, and our research universities—and there are three research universities in the Oregon university system, those being Portland State, Oregon State, and Uni-

versity of Oregon—all have approximately 20,000 students. That makes them rather small by national standards, compared to, say, a University of Wisconsin, with, what, 90,000. And so, as research and the economic development contribution of universities became more important, a shift in thinking took place, starting 7 or 8 years ago, that, instead of competing for relatively small investments that the State of Oregon is able to make, it was a much smarter thing to do to join forces and have the universities collaborate with each other on joint proposals, sharing facilities, which we do, in order to be more competitive internationally. It has worked better, I think, than anyone ever expected. The leadership, from the presidents on down to the campuses, get along extremely well. I have a leadership team consisting of faculty leaders from all three universities and Pacific Northwest National Laboratory. There are joint inventions, there are successful proposals and exciting projects that simply could not have happened had we not decided to collaborate.

Senator SMITH. Are you seeing this being copied by other States?

Mr. RUNG. Yes. I think—although I'm not as familiar, of course, with other States' work as I am—I hear of things like this happening in Virginia and Maryland, for example. And so, I think it's—it's not an unheard-of topic at all. People recognize the importance of collaboration. Collaboration being so necessary if you want to assemble resources quickly, to attack an opportunity rather than spend a great deal of time building or hiring what you don't have.

Senator SMITH. Do any of you have any questions for him?

In the interest of Senator Allen's time, he'd like to have his witness from Virginia go next. And so, if you don't mind, we'll go to Mr. Gwaltney, and you go next.

Senator ALLEN. Thank you, Mr. Chairman.

STATEMENT OF JERRY L. GWALTNEY, CITY MANAGER, CITY OF DANVILLE, VIRGINIA

Mr. GWALTNEY. Thank you, Mr. Chairman, distinguished Chairman Stevens, and, of course, Senator Allen—my name is Jerry Gwaltney. I'm the City Manager of the City of Danville. And Danville is an independent city located on the Dan River on the border of North Carolina.

Strategically located on the mid-Atlantic Coast, Danville is within 1 day's driving distance to over two-thirds of the United States population. The city has a population of 48,000-plus, and has lost a tremendous number of basic employer jobs over the past 24 to 36 months. In fact, the job losses have caused the unemployment rate to hover at more than double the state average. Today, it was announced in the paper that it's 11.9 percent, and it stays there most often. Furthermore, the Danville MSA has held the position of the state's highest MSA unemployment level for 2 years or more. A total of 58 metropolitan areas suffered total job losses over the year ending September 2005. Danville lost 2,400 jobs. This places Danville in the top four metropolitan areas in areas with job loss. Only three areas ranked higher than Danville. All three are located in areas devastated and ravaged by hurricanes.

In order to reinvent the economy, the city is in the forefront of the establishment of infrastructure and the creation of an atmos-

phere conducive to establishing a nanocluster. I would like to share with you today the clear vision and subsequent path the city of Danville is engaging in, and further detail for you our efforts and success in utilizing nano as a crucial element in the transformation of our economy.

Our goal in the city is rooted in, and grown from, the need to diversify our economy. Knowing we would face a decline in our traditional industries, tobacco and textiles, the city placed a proactive focus on evaluating the global economy and refining a vision that would serve as a catalyst for us and our local economy. In this case, and relative to today, the focus is on nano.

Our efforts have been built on three equally important elements: education, a hands-on governmental approach, and private investment in technology. Through collaboration, partnership, and implementation, we've had success and recruited a nanotechnology facility now in place, and are confident additional interests will continue to unfold.

I would like to take a moment to briefly focus on our collaborative efforts, as they have been, without a doubt, innovative and truly a template others can use as a model.

The efforts began with creating an atmosphere of learning and interest, through schools, which—such as the Galileo High School, a school that was enabled through a Federal magnet grant which focuses on biotech, information technology, and aerospace. The efforts continue through the creation of infrastructure such as the Cyber Park, fiber network, business incubator, and the foundation for a nanocluster in our historic tobacco warehouse district redevelopment area.

We have shaped our environment into one that is user-ready for various technology-focused companies, including nanotechnology. There's no doubt that Luna nanoWorks has been a catalyst for other companies selecting our area.

Our efforts have been long thought out and aggressively sought after, yet would not be possible without numerous collaborative efforts. Our partners range from our neighboring county to Federal entities, such as EDA, along with hard work from a good Senator named Senator Allen—George Allen, and, of course, his colleagues, Senator Warner and Congressman Goode.

We have invested in several key technology-based economic development assets, such as the Institute of Advanced Learning and Research and the Regional Center for Advanced Technology and Training, with the assistance from the Commonwealth of Virginia, the Tobacco Indemnification and Revitalization Commission, and various educational partners, to include Virginia Tech.

We have a technology business incubator, which has been sponsored by EDA. This environment, along with our current nanomaterials manufacturing facility, Luna nanoWorks, a division of Luna Innovations, Incorporated, helps to secure Danville's position as a leader in technology, especially in the nanoscale.

Luna is an ideal example of our intentions coming to fruition. It supports the idea that through government support a realistic effort exists in creating a nanoecosystem, of which nanotechnology research transference to the marketplace can take place regardless of the size or location of the ruralness of a community. Specifically,

the Luna project's scope was $6.5 million in investment, with the creation of 54 high-technology jobs over a 30-month period. Of course, I'm interested in what it can do for the support people who need to transfer to those jobs, also.

Today, Luna is 25 employees strong, and growing—15 Ph.D.'s, including two world renowned fullerene scientists, a member of the American Academies of Science, and a successful pharmaceutical entrepreneur make up this high-caliber company. Their presence has led to a very creative partnership for education excellence, K–12 and higher education, including significant work toward a graduate program at the Institute for Advanced Learning and Research in Nanotechnology. This success story owes its happy ending to a collaboration of a lot of people.

And in your words, Mr. Chairman, and I quote, "Nanotechnology is creating opportunities that range from improving sports equipment to inventing lifesaving medical applications. Competition in nanotechnology is global in nature. Other countries, such as Japan and China, are making tremendous investments, and it's critical that we maintain global leadership."

Looking at it from a city manager's perspective, think what research can do for a city's operation by developing nanotextile materials that protect the policeman that's being shot at, or create better automobiles for use in city operations, or enhances our regional medical facilities. So, not only does nanomaterials and research assist in forming an economic basis for the community, it can also provide worldwide commercialization to help a city like Danville compete in the global economy.

Senate bill 1908 positions the United States to retain its competitive position with respect to nanotechnology on a global scale. The bill's approach to building a collaborative partnership between private sector, the Federal Government, and major research institutions is exactly what is needed. The creation of eight Nanoscience to Commercialization Institutes, in my opinion, is right on target. In fact, Danville stands as an example of what this bill could accomplish on a much larger scale.

In closing, Mr. Chairman, when you get the bill passed, I want one in Danville, Virginia. And that's——

[Laughter.]

Mr. GWALTNEY. So—but let me say how important this is to our economy.

Senator SMITH. I know somebody who can help you——

[Laughter.]

Mr. GWALTNEY. He's been very much of a help.

Let me add one other thing here. I made a note—somebody mentioned $100,000 per year. And—but I also wrote "support people," the people that won't make the $100,000 a year, but they can come out of the textile industry and the tobacco industry, which is no longer there, and be the support people and make decent salaries with regards to this.

By the same token, when you bring something like this into a community such as I serve, which is a very rural area, and one that's been hard hit by NAFTA, you bring people in that change your school system, change your education system, and change what the demands are on the community to make that community

lift itself up and bring the right kind of jobs to the people who are trying to better themselves.

So, while I'm not the expert on the technology that the other gentlemen have mentioned here today—I'm here because of jobs and what nanotechnology can do for jobs and make a community competitive. It is an example and hopefully has given you some brief that we've been there and done that, and we've used this as a vision and a basis to make us a better place to be.

Thank you for your time, sir.

[The prepared statement of Mr. Gwaltney follows:]

PREPARED STATEMENT OF JERRY L. GWALTNEY, CITY MANAGER, CITY OF DANVILLE, VIRGINIA

Mr. Chairman, Senator Allen and distinguished members of the Committee, thank you for the opportunity to appear before you and testify today on the establishment of the Nanoscience to Commercialization Institutes Act (S. 1908.)

I am the City Manager of the city of Danville, Virginia. The independent city of Danville is located on the Dan River in the southern central portion of Pittsylvania County along the North Carolina Border. Strategically located on the mid-Atlantic coast, Danville is within 1 day's driving distance to over two thirds of the United States' population. Excellent highway and rail systems provide ready access to major northern and southern metropolitan and manufacturing markets.

The city of Danville has a population of 48,411 and has lost a tremendous number of basic employer jobs over the last 24–36 months. These job losses have caused the unemployment rate to hover at more than double the state average (11.9 percent February 2006 versus VA at 3.3 percent for that same month). Furthermore, the Danville MSA has held the position of the state's highest MSA unemployment level for 2 years or more.

A total of 58 metropolitan areas suffered total job losses over the year ending September 2005. Danville lost 2,400 jobs. This places Danville in the top four metropolitan areas with job loss. Only three areas ranked higher than Danville. All three are located in areas devastated and ravaged by hurricanes. The entire South Atlantic region has lost a total of 20,300 manufacturing jobs. The city of Danville alone claims over 8 percent of that regional total.

In order to reinvent the economy, the city of Danville is in the forefront of the establishment of infrastructure and the creation of an atmosphere conducive to facilitating a nano cluster. I would like to share with you today the clear vision and subsequent path the city of Danville is engaging in and further detail for you our efforts and success in utilizing nano as a crucial element in the transformation of our economy.

Our goal in the city of Danville is rooted in and grown from the need to diversify our economy. Knowing we would face a decline in our traditional industries, tobacco and textiles, the city placed a proactive focus on evaluating the global economy and refining a vision that would serve as a catalyst for us and our local economy. In this case, and relative to today, the focus is on nano.

Our efforts have been built on three equally important elements: education, a hands-on governmental approach (local, regional and in partnership with the Commonwealth) and private investment in technology. Through collaboration, partnership and implementation we have had success and recruited a nanotechnology facility, now in place, and are confident additional interest will continue to unfold.

I would like to take a moment to briefly focus on our collaborative efforts as they have been without a doubt innovative and truly a template others can use as a model. The efforts began with creating an atmosphere of learning and interest through schools such as the Galileo High School, a school enabled through a Federal magnet grant, which focuses on biotech, information technology and aerospace. The efforts continue through the creation of infrastructure such as a Cyber Park, fiber network, business incubator and the foundation for a nano cluster in our historic tobacco warehouse district redevelopment area. We have shaped our environment into one that is user ready for various technology-focused companies, including nanotechnology. It is no doubt that Luna nanoWorks has been a catalyst for other companies selecting our area.

Our efforts have been long thought out and aggressively sought after, yet would not be possible without numerous collaborative efforts. Our partners range from our neighboring county, Pittsylvania, to Federal entities such as EDA along with hard

work from our strong supporters; Senator Warner, Senator Allen and Congressman Goode. We have invested in several key technology based economic development assets such as the Institute of Advanced Learning and Research (IALR) and the Regional Center for Advanced Technology and Training (RCATT), with the assistance from the Virginia Tobacco Indemnification and Revitalization Commission, the Commonwealth of Virginia and various educational partners including Virginia Tech. We have a Technology Business Incubator through the contributions of EDA, the city and county. This environment, along with our current nano materials manufacturing facility, Luna nanoWorks, a division of Luna Innovations Incorporated helps to secure Danville's position as a leader in technology—especially in the nanoscale. Luna is an ideal example of our intentions coming to fruition.

Luna is an example of how the city of Danville has bridged the gap in between vision and implementation. It supports the idea that through government support a realistic effort exists in creating a nano ecosystem from which nanotechnology research transference to the marketplace can take place regardless of the size or location of the community.

Specifically, the Luna project scope was $6.5 million in investment with the creation of 54 high technology jobs over a 30-month period. Today, Luna is 25 employees strong and growing. Fifteen Ph.D.'s, including two world renowned Fullerene Scientists, a member of the American Academies of Science, and a successful pharmaceutical entrepreneur make up the scientific leadership team for this high caliber company. Their presence has led to a very creative partnership for educational excellence K–12 and higher education, including significant work toward a graduate program at the Institute for Advanced Learning & Research in nanotechnology. This success story owes its happy ending to a coalition of forces including the city of Danville, who purchased a building that is leased to Luna, the Governor's Opportunity Fund, the Tobacco Region Opportunity Fund, DBA workforce services, higher educational institutions, the SBA Hubzone, etc.

In your words Mr. Chairman, "Nano technology is creating opportunities that range from improving sports equipment to inventing life-saving medical applications. Competition in nanotechnology is global in nature. Other countries, such as Japan and China are making tremendous investments and it's critical that we maintain global leadership."

Looking at it from a City Manager's perspective, think what research can do for a city's operation by developing nano textile materials that protect the policeman that's being shot at or create better automobiles for use in city operations, or enhances our medical facilities. So not only does nano materials and research assist in forming an economic basis for the community, it can also provide worldwide commercialization to help a city like Danville compete in the global economy.

Senate bill 1908 positions the United States to retain its competitive position with respect to nanotechnology on a global scale. The bill's approach to building a collaborative partnership between the private sector, the Federal Government and major research institutions is exactly what is needed. The creation of 8 Nanoscience to Commercialization Institutes, in my opinion, is right on target. In fact, Danville stands as an example of what this bill could accomplish on a larger scale. In closing, Mr. Chairman, when you get the bill passed I want a Nanoscience to Commercialization Institute for Danville.

Again, thank you Mr. Chairman and Members of the Committee for your time and this opportunity to address you today.

LUNA NANOWORKS—NANOMANUFACTURING FACTSHEET

Project Summary

Cost-effective nanomaterials are needed for research and development of new defense and industrial applications. High volume production addresses the global need for large quantities of nanomaterials at a reduced cost. In a former tobacco warehouse in Danville, Virginia, Luna nanoWorks' focus is to be a leading manufacturer of carbonaceous nanomaterials.

What are Luna's Nanomaterial Technologies?

Luna is a leader in nanotechnology with a focus on the manufacturing and application of carbon-based nanomaterials. Luna's nanomaterial technologies include carbon nanomaterials, empty cage fullerenes, and high purity carbon nanotubes. Luna's intellectual property position includes exclusive licenses, patents and inventions relating to manufacturing, modification, and application of these new nanomaterials. For example, TRIMETASPHERE™ carbon nanomaterials are a newly discovered class of molecules owned exclusively by Luna. TIMETASPHERE™ carbon nanomaterials consists of three rare earth metals (*i.e.,* Scandium, Lutetium, Holmium, Gadolinium)

inside a molecular cage formed of carbon atoms. Luna has successfully translated the research that conceived of these materials into a commercial reality.

What are the Commercial Applications?

Luna is developing high value, carbonaceous materials for defense and commercial applications.

Luna is focused on several defense applications including conductive coatings and sealants to improve stealth, low friction coatings to keep engines running with loss of lubricant, and high performance wearable solar cells. Luna's carbonaceous nanomaterials have also been demonstrated as single molecule devices for molecular computing and data storage.

A critical commercial application of TRIMETASPHERE™ carbon nanomaterials will be a new generation of medical diagnostic agents. Trimetasphere-based contrast agents for medical imaging offer the potential for improved performance and safety over competitive technologies. As an example, initial testing has shown that Trimetaspheres® nanomaterials can be used to provide medical images with 25x the resolution of leading technologies. The nature of the molecular cage protects patients from the metal atoms used for imaging, improving patient safety. Better diagnostic performance and safety results in improved patient outcomes and reduced health care costs. Trimetaspheres® nanomaterials also can be used as targeted diagnostics, enabling physicians to precisely locate cancer cells, blood clots, etc. for more effective diagnosis and treatment.

Why is this Project Important?

- *For Danville*—This project transforms the Southside economy and promotes a high-technology image for the region with *"new economy" jobs.* This division is projected to employ more than 50 people by 2006.
- *For Virginia*—Virginia has achieved national recognition in nanotechnology, as the Commonwealth's leading research universities, laboratories, and small businesses continue to produce groundbreaking work in the field. This project further establishes Virginia as an *international leader in nanotechnology.* Luna's headquarters, research, and manufacturing facilities are located in Virginia.
- *For the U.S.*—There are limited supplies of highly pure carbonaceous nanomaterials to *meet the ever increasing need in research and development.* This results in keeping nanomaterial costs high while preventing widespread development. Luna is a U.S.-owned manufacturer and developer of nanomaterials and will be able to supply needed amounts of product necessary for defense applications. Luna intends to work with the Department of Defense on the research and development of products for the future, and to create high quality jobs in the U.S.

Who were Luna's Collaborators in establishing nanoWorks in Danville?

Partners include:

- U.S. Senator John Warner
- Governor Mark Warner, Secretary of Commerce & Trade Michael Schewel and the Virginia Economic Development Partnership
- U.S. Congressman Virgil Goode and the Virginia Tobacco Commission (Carthan Currin, Executive Director)
- City of Danville Office of Economic Development (Ron Bunch, Executive Director)
- Virginia Department of Business Assistance's Workforce Services Program

How Did the SBIR and ATP Funding Assist?

Luna nanoWorks was aided by NSF programs that focused on production and separation technology and a NIST Advanced Technology Program for high-risk research and development of carbon nanomaterials for medical applications. The company continues to work on Department of Defense applications and is scaling up its manufacturing of nanomaterials for bulk supply.

Who is Luna Innovations?

Luna nanoWorks is a division of Luna Innovations Incorporated—an employee-owned business, headquartered in Virginia (*www.lunainnovations.com*). Luna's business model is—Invent, Build and Commercialize. Luna is accelerating the innovation process, utilizing the vast resources of our Nation's universities and Federal laboratories to address critical defense and commercial market needs.

Utilizing Small Business Innovation Research and NIST Advanced Technology Program awards, corporate partnerships and venture capital, Luna has developed cutting-edge products that improve the diagnosis and treatment of disease, enhance

the way the world communicates, and provide a brighter future for our energy needs. Most recently, Luna's products are centered on breakthroughs in nanomaterials technology. Luna has created hundreds of high quality jobs in the State of Virginia and has research and manufacturing facilities in Blacksburg, Charlottesville, Hampton, Danville and McLean.

NANOMATERIALS—AN INDUSTRY LEADER IN NANOTECHNOLOGY, LUNA IS MAKING PRODUCTS EMPOWERED BY NANOMATERIALS.

Nanomaterials are components that enable engineering at the atomic scale. The assembly of composites using nanomaterials can achieve a degree of miniaturization and control of processes unprecedented in typical manufacturing. Luna nanoWorks, a division of Luna Innovations Incorporated, understands that the value of nanomaterials depends on the benefits provided to end-use products in which they are incorporated. The division is focusing on materials manufacturing and proprietary products based on carbon nanomaterials.

TRIMETASPHERE™ carbon nanomaterials are a newly discovered class of compounds that are exclusive to Luna. This patented class of novel molecules comprises 80 carbon atoms forming a sphere which encloses a complex of three metal atoms in a nitride configuration. TRIMETASPHERE™ carbon nanomaterials can include metallic atoms of the Group IIIB and lanthanides, including Scandium. Different metals, each providing unique attributes, can be incorporated. For example, Gadolinium and Holmium TRIMETASPHERE™ carbon nanomaterials ($Gd_3N@C_{80}$, and $Ho_3N@C_{80}$) have paramagnetic nuclei that could dramatically enhance the contrast for medical Magnetic Resonance Imaging (MRI) procedures and revolutionize medical diagnostics. These agents are nano-engineered to maximize the impact of the magnetic field on the water protons to achieve higher contrast. $Gd_3N@C_{80}$ is the only molecule that enables radiologists to administer a targeted Gd-based contrast agent to a specific target without the risk of metal toxicity.

Luna offers $Ho_3N@C_{80}$ Trimetasphere® as a building module for researchers that wish to track the distribution of their molecule after administration in animals. Holmium provides high relaxivity, which means sharper contrast and image resolution. The reagent kit provides Trimetaspheres to researchers and they can attach and customize their targeting species.

Luna's Scandium TRIMETASPHERE™ carbon nanomaterials ($Sc_3N@C_{80}$) have unique electron transport properties that could improve organic solar panel performance. Organic solar cells are lightweight, flexible and less expensive than inorganic solar cells but have not been widely used as they do not presently convert enough of the sun's light into electrical energy. Luna is developing a novel derivative of $Sc_3N@C_{80}$ that is designed to enhance organic solar cell performance which will make a more popular choice.

Luna's expertise in TRIMETASPHERE™ carbon nanomaterials includes synthesis, purification, functionalization and specific application development for defense and commercial requirements. Due to encapsulated metal variations, each species may be used for applications exhibiting different mechanical, electrical, optical and magnetic behavior based on end user needs.

Single Wall Carbon Nanotubes (SWCNTs) consist of a single, rolled-up sheet of atomic carbon hexagons that are 50,000 times thinner than a human hair. These hollow, cylindrical molecules of pure carbon are reported to be extraordinarily strong (100 times stronger than steel of the same weight) and flexible. Nanotubes can vary in diameter and in the pitch of the spiral formed by tracing each row of contiguous six-membered rings. The term for the different spirals is "chirality". With different chirality nanotubes have different electrical properties. Some behave like insulators, preventing electricity from flowing, some are highly conductive and some are semiconductors.

The potential for creating nano-scale electrical circuits is but one exciting possibility using Luna's SWCNTs. In addition to their mechanical properties, SWCNTs have excellent thermal conductivity. Luna is working to integrate this property into textiles to create next-generation garments that could eliminate heat quickly by harnessing the power of the nano-scale.

Higher Fullerenes—The original Buckminster Fullerene is a C_{60} sphere in which the carbon atoms are all covalently bound to each other in a structure that resembles a soccer ball. Carbon atoms can pack together in other arrangements, as demonstrated in the figure above. Each of these higher fullerenes has a different pattern of electrons which convey unique physical and chemical properties while allowing for unique electron affinities. This allows Luna to tune the electronic properties of nano-structured composites using different mixtures.

Luna nanoWorks is taking advantage of its ability to manipulate the properties of their materials to engineer nanomaterials into a number of systems in specific products for the Department of Defense and others. Nano-empowered products under development include:

- Composites
- Coatings
- Paints
- Plastics
- Medical Diagnostics
- Therapeutics

Senator SMITH. Mr. Gwaltney, I don't really have a question for you, but I sure have about a dozen rural towns in Oregon I'd like to have listen to your testimony, because so many places of rural America were built by oldtime industries, and the products from those industries have passed or become uncompetitive, and I think you're setting the standard for how rural places can participate in the flat world economy at the highest levels of technology.

Mr. GWALTNEY. No doubt. We've had a lot of companies come just because they are there. But I think another important thing, Mr. Chairman, is that people say that these highly educated Ph.D.s don't want to come, they want to go to these universities. Well, there has to be that tie-in with their institutions and in research as we—such as we have done with Tech and the Institute. But I find that many of them would like to get in that kind of area, and they will come if the research and the capabilities are there for them to carry on their work.

Senator SMITH. Senator Allen?

Senator ALLEN. Thank you, Mr. Chairman. And thank you for inviting, at my request—I wanted Luna Technologies to come, but we said, "Well, let's get Mr. Gwaltney."

I've talked to the folks at Luna, and all these things we talk about are important, but so are people. One of the reasons Luna is there is Jerry Gwaltney. He's one—they said, "We're interested in certain things," and they could take his word to the bank. And persons still matter in this world of technology, and he's one that—I'll tell you, they are facing the toughest thing, Danville and just a little bit to the west there, in Martinsville. They have lost literally thousands of textile jobs, some of them being lost right before Christmas. It's worse than a natural disaster when these—whether it's Dan River or Toltechs or others shut down. At least when there's a natural disaster, you can build back. But there are generations that have worked, and they lose these jobs due to international competition.

And the transformation and the inspiration from what they're doing in Danville is very important. Where Luna is, they're now fabricating or manufacturing these Trimetaspheres, which——

Mr. GWALTNEY. Yes.

Senator ALLEN.—can have all sorts of applications in life sciences, as well as some of the materials sciences. But what's most interesting is, where they're located is in the old tobacco warehouse district. So, they're in where the old economy was, building the most advanced intellectual property that they actually——

Mr. GWALTNEY. Yes, sir.

Senator ALLEN.—own the trademark and the patents on this. And so, things are tough right now in Southside Virginia, with the

decline of tobacco and textiles and, in some cases, wood bedroom furniture, as well. But these folks are fighting back. They are adapting as best they can.

The universities do matter. There's an institute that was created down there in Danville with the community college, Averett. But the key was Virginia Tech. And Virginia Tech—I think that really does help a great deal. And I commend you, Mr. Gwaltney and all the folks in Danville and Pittsylvania and Southside Virginia for hanging tough. And I look at nanotechnology as the next economic revolution. And we need to be in the lead. And for the hardworking people and creative folks, whether it's in Danville or whether it's anywhere else in this country, we need to make sure that we're on the lead of it. And a place like Danville, if you all can do it, you're a model for others, as well. We're really proud of you. Count me as a continued teammate.

Mr. GWALTNEY. You certainly have been, and we certainly will continue to count on you.

Now, let me just close by one more thing—one more thing that—I'm going to go back to what Chairman Smith said. I've had a chance, from an economic development standpoint, to travel to India and China and some of those places with regards to—and what they're doing to us. And I've seen that, firsthand. And to do something like this, that Chairman Smith is trying to do, I think, is the—really the most important thing that can be done for communities such as us. And, as you said early on, so many are at the—or Chairman Stevens or someone said—they're in different places, and they're where the institutions are, and what have you. If you can broaden this and make it something that can go out into the communities and bring those institutions together with the private research and the incentive programs and put—together by the local governments and the Commonwealth of Virginia, which Governor Allen was very familiar with, as Governor—it is very important to the livelihoods of communities such as mine that has been devastated with unemployment due to NAFTA and those type things.

Thank you.

Senator SMITH. Well, thank you. I think most of the public, when they hear nanotechnology, they're afraid we're talking about a nanny state or something——

[Laughter.]

Mr. GWALTNEY. That's right.

Senator SMITH.—and what this hearing's all about is what you're doing, and that is to make this real, in terms of products, in terms of jobs, in terms of American leadership on planet Earth. And so, you're a great witness and a great story.

Mr. GWALTNEY. Thank you, sir. Just one more thing. When they brought me that little black soot, I'll call it, that was supposed to be so—product of the nanomaterial, which I knew nothing about, I looked at our economic development, Ron Bunch, who is behind me, and said, "What in the heck is this?" But it has proven to be something really worthwhile. And the byproduct to our local educational system as—will do exactly what you all were talking about earlier, train these youngsters, get these youngsters into it. They're into—these people are into our school systems, and it's bringing

tech into our school systems. And that's the way we're going to build the future scientists that Senator Allen and you want so much.

Thank you.

Senator SMITH. Well, thank you.

And thank you, Dave Rejeski, for your patience. You're going to bat cleanup here today. And so, the mike is yours.

STATEMENT OF DAVID REJESKI, DIRECTOR, PROJECT ON EMERGING NANOTECHNOLOGIES, WOODROW WILSON INTERNATIONAL CENTER FOR SCHOLARS

Mr. REJESKI. Great. I'd like to thank you, Chairman Smith, and also Ranking Member Dorgan and other Members of the Committee, for holding this hearing.

My name is Dave Rejeski, and I direct the Project on Emerging Nanotechnologies at the Woodrow Wilson Center.

Let me begin by talking a little bit about the state of commercialization. In February, our project released the first public inventory of nanotech-based consumer products. This suite of already commercialized products tells us something about the challenges we're going to face as we begin to introduce nanotechnology into the marketplace. In the end, it's going to be a test of our policies, our resolve, and our ingenuity.

We found 230 products, and we believe this is a significant underestimate. And I've brought a few of these products with me. We can talk about them, if you'd like.

These products have been commercialized predominantly by small- and medium-sized firms, most of them in the U.S. The products are entering the marketplace in areas where oversight and regulations are relatively weak, in the areas of cosmetics and dietary supplements. And commercialization is global. We found products essentially from 15 countries already.

Senator SMITH. Fifteen?

Mr. REJESKI. Fifteen countries.

In late March, the world experienced what may be the first nanotechnology accident resulting in adverse health effects, involving a German product, a bath and tile cleaner called Magic Nano. The product had significant health impacts. Over a hundred people were affected with respiratory problems, six people were hospitalized. In addition, a lack of disclosure concerning the ingredients on the product has prevented a timely resolution in the case. And a third-party testing label highly trusted by the German public, much like our UL label, was misused on this product, which is a serious offense.

So, something is going right. We can begin to see these products are being commercialized, but clearly things can go wrong if we fail to provide the right oversight.

One of the greatest enemies of commercialization is uncertainty—uncertainty about the risks, about regulation, and about public acceptance. Pervasive uncertainty is going to limit, ultimately, the flow of critical investment capital into what Sean described as the "Valley of Death."

Let me provide just three recommendations to improve the overall climate for commercialization in this country. It will help firms. It's going to help investors. And it's going to help consumers.

First, there's been an incredibly surprising degree of consensus between industry, trade associations, think tanks, and NGO's concerning the need for more environmental health and safety research funds and the need to make sure these funds are strategically allocated to deal with existing and emerging risks. We need to put the research in front of the product flows to both inform our oversight strategies with good science and to provide important information on risks and benefits to the public.

Second, for commercialization to succeed, we need an oversight system that's transparent for business, that's efficient, and predictable. We don't have that now. Companies are unsure about the regulatory intentions of the Government right now, investors are insecure, and the public is largely uninformed. Short of new legislation, there is much more Government and industry can do to provide adequate oversight of emerging products. One approach is applying a portfolio-of-initiative strategy to key product areas. Using just cosmetics as an example, we could put together the FDA's voluntary registration program with what industry does on ingredients review, couple that with some labeling guidelines and more consumer education. In other words, we put together a portfolio of approaches.

Finally, I think we've waited too long to really engage the public about nanotechnology. Successful commercialization without strong consumer confidence, is just not possible. So, we need resources for public engagement. They need to be increased by orders of magnitude, and efforts rapidly accelerated.

If we don't address these broad issues affecting the climate for commercialization, I think the work of any of the commercialization institutes, such as those being considered by the Subcommittee, is going to be severely handicapped, and a lot of innovations could essentially die on the laboratory bench.

There are also a few more focused activities that could be undertaken to complement the proposal in the bill, which I support.

First, I think that commercialization policies and the programs need to be informed by rigorous data about the firms, their products, their issues, and their needs. We need to get some people on the ground collecting data. I think the Commerce Department should work to collect and continually update survey data on nanobusinesses, working as needed with other data-collection arms of the U.S. Government, whether it's the Bureau of Labor Statistics, the Census Department, whatever.

Second, I also think we need a one-stop-shop at a Federal level focused on integrating our efforts that are critical to commercialization. I'd call it the Interagency Nano Business Office. The existing National Nanotech Coordinating Office does a good job, but it was set up to coordinate science, not to drive innovations to market. So, I think a one-stop shop would complement the nanoscience commercialization institutes being proposed in S. 1908, and also help bring a lot of the policy discussions together at a Federal level, and that would help us in our interactions internationally.

I think we should use the purchasing power of the government, at Federal, state, and local levels, or quasi-governmental organization such as the Postal Service, to create early markets for critical nanotech-based products, especially in the energy application area, such as lighting, photovoltaics, fuel cells, and batteries.

Finally, I think we begin now to develop an export-promotion strategy to help U.S. nanotech firms in what's going to be an incredibly tough and highly competitive global market. That means engaging agencies that have been largely on the sidelines of the national nanotech initiative, but are going to play increasingly important roles in commercialization, such as the Export-Import Bank and the Trade and Development Agency.

There's one caveat that applies to everything that I have said here. Any government program, policy, or strategy, has got to work for our small businesses. They are essentially the heart of the nanotech revolution.

I'd like to close by saying that I applaud the Committee for focusing our attention on the issues of commercialization. Nanotechnology is no longer just a large government science project. In the long run, key social and economic benefits will only occur if we succeed in bringing innovations to market.

Thank you.

[The prepared statement of Mr. Rejeski follows:]

PREPARED STATEMENT OF DAVID REJESKI, DIRECTOR, PROJECT ON EMERGING NANOTECHNOLOGIES, WOODROW WILSON INTERNATIONAL CENTER FOR SCHOLARS

I would like to thank Subcommittee Chairman Gordon Smith, Ranking Member Byron Dorgan, and the members of the Senate Subcommittee on Trade, Tourism, and Economic Development for holding this hearing on promoting economic development opportunities through nanotechnology commercialization.

My name is David Rejeski, and I am the Director of the Project on Emerging Nanotechnologies at the Woodrow Wilson International Center for Scholars. The Project on Emerging Nanotechnologies is an initiative launched by the Wilson Center and The Pew Charitable Trusts in 2005. It is dedicated to helping business, government and the public anticipate and manage the possible health and environmental implications of nanotechnology. The Project collaborates with researchers, government, industry, nongovernmental organizations (NGO's), and others concerned with the safe applications and utilization of nanotechnology.

Our goal is to take a long-term look at nanotechnologies, to identify gaps in the nanotechnology information, data, and oversight processes, and to develop practical strategies and approaches for closing those gaps and ensuring that the benefits of nanotechnologies will be realized. We aim to provide independent, objective information and analysis which can help inform critical decisions affecting the development, use, and commercialization of nanotechnologies throughout the globe.

In short, both the Wilson Center and The Pew Charitable Trusts believe there is a tremendous opportunity with nanotechnology to "get it right." Societies have missed this chance with other new technologies and, by doing so, forfeited significant social, economic, and environmental benefits.

As the Subcommittee knows, nanotechnology is expected to become the transformational technology of the 21st century. It is the world of controlling matter at the scale of one billionth of a meter, or around 1–100,000th the width of a human hair. Researchers are exploring new ways to see and build at this scale, reengineering familiar substances like carbon and gold in order to create new materials with novel properties and functions.

As the National Science Foundation (NSF) highlights, the ability to create novel properties in materials and systems at this scale implies that nanotechnology eventually could impact the production of virtually every human-made object—everything from automobiles, tires, and computer circuits to advanced medicine and tissue replacements—and lead to the invention of products yet to be imagined.[1] Nanotechnology will fundamentally restructure the technologies currently used for manu-

facturing, medicine, defense, energy production, environmental management, transportation, communication, computation, and education.

The Landscape of Nanotechnology Commercialization

It would have been difficult to address the state of commercialization just one year ago. In March 2006, our project released the first public inventory of nanotech-based consumer products.[2] This suite of already-commercialized products tells us something about the emerging face of the nanotechnology industries and the challenges we face as we begin to introduce nanotechnology into the marketplace. It is a test. Our ability to reap the long-term benefits of nanotechnology—in areas from medicine to energy and food production—will depend heavily on how we manage the introduction of this first generation of consumer products. More complex products, with large societal implications, will soon be upon us. For example, there are currently 130 nano-based drugs and delivery systems and 125 devices or diagnostic tests in preclinical, clinical, or commercial development—an increase of 68 percent percent since last year.[3] We are about to be inundated with hundreds, if not thousands, of new products.

In analyzing our nanotechnology consumer products inventory, we found that:

- There are 230 products on the market. We believe this number is a significant underestimate because the inventory only contains nanotechnology products self-identified by the manufacturer. This does not include the "over 600 raw materials, intermediate components and industrial equipment items" that EmTech Research projects are currently in use by manufacturers.[4]
- These consumer products have been commercialized predominantly by small and medium sized enterprises (our estimate is that roughly two-thirds of products are from small or medium sized businesses).[5]
- Products are entering the marketplace in areas where regulations and oversight are weak, for instance, in the areas of cosmetics (31 products), dietary supplements (13 products), and consumer products (at least 135 products). Many of the products we found have high exposure potential, being used directly on the body or actually ingested. In short, we are facing a situation in which nano-based products are entering the market at precisely the points where government regulation and oversight are imperfect and imprecise and potential exposure is high.
- Commercialization is already global. We found products from 15 countries.[6] Nanotechnology will continue to mature in a global digital economy where products can be bought and sold on the Internet and flow quickly across international boundaries through both business-to-consumer and business-to-business Internet transactions. This trend in global e-commerce will present new challenges for our oversight system, as products can be shipped, transported, and traded between nations with varying environmental, health, and safety laws. The lack of international agreements on labeling products that contain nanomaterials further complicates this issue.

In late March in Germany, the world experienced what may be the first nanotechnology incident resulting in adverse health effects—from a bath and tile treatment called "Magic Nano." The product allegedly had significant health impacts, with 100 people affected with respiratory problems and six hospitalized with pulmonary edemas.[7] Other issues have since emerged around "Magic Nano" that are critical to our ability to commercialize new nanotechnology products in the future, including:

- A lack of disclosure concerning the ingredients in the product has prevented a timely resolution of the case and determination of whether and how nanotechnology might have been implicated. A panel of German government experts was unable to determine whether nanomaterials were the cause of health problems because "the distributors of the two sealing sprays were unable to supply the full formulations because information was missing from their upstream suppliers." [8]
- It appears that a third party testing seal, highly trusted by the German public (TÜV), was misused on this product. The head of the Federation of German Consumer Organizations noted that "It is irresponsible to give the consumers a mistaken sense of security by falsifying stamps." [9] This case has been referred to the district attorney, and there are calls for a criminal investigation against the manufacturer for suspected violation of Germany's product safety laws. This is analogous to the misuse of the Underwriters Laboratories (UL) symbol in the United States, which has occurred recently with respect to fireplaces,[10] extension cords,[11] and table saws.[12] Further complicating this issue is that these third-party certification bodies test products more for performance than for potential health or environmental risks. Even if such bodies were called upon to test products containing nanomaterials, no clear, agreed-upon test protocols exist.

Regardless of how this case plays out, the lack of transparency and issues with independent testing have serious implications for public perceptions. When asked what would help increase public trust in government to manage the risks posed by nanotechnology, a number of studies conducted around the world have reached two conclusions: greater transparency/disclosure and the use of third party, independent safety testing. The "Magic Nano" case indicates that both of these principles can be violated and that a similar situation could occur just as easily in the United States or other developed countries. The incident may be local, but the press is global.

Challenges Facing Nanotechnology Commercialization

Lack of Effective Oversight Mechanisms

Something is going right—products are being commercialized—but, clearly, things can go wrong if we fail to provide the adequate oversight, as the "Magic Nano" case in Germany illustrates.

Though agencies have been meeting to discuss oversight and the EPA has begun developing a voluntary data collection program, our approach on the regulatory side so far has been ad hoc and incremental, with no vision. It is particularly worrisome that many nanotechnology-based consumer products are entering the market in areas with little government oversight, such as cosmetics and dietary supplements. The U.S. Government approach has been limited by the following:

- A focus on single statutes such as the Toxic Substances Control Act (TSCA) rather than taking an integrated, multi-statute approach;
- A focus on products more than the facilities and processes where production occurs;
- A general lack of concern with the full life-cycle impacts of emerging nanotechnologies (an approach recommended in the 2004 U.K. Royal Society Report); [13]

- Too little resources devoted to pollution prevention and the "greening" of nanotechnology products and production processes, which could help industry and society ultimately avoid potential risks from the beginning; and
- Inadequate discussion of the resource constraints to effective oversight (for instance, do we have the personnel, expertise and dollars in the agencies needed for enforcement or testing?).

Most important, we have not looked forward to consider where nanotechnology is heading, assuming instead decades-old risk management policies and analogies to the past will help us respond to the risks of the future. Today, nanotechnology is largely chemistry and materials science. But it is quickly becoming chemistry and biology. After that, we will be dealing with multifunctional machines operating at the interface of classical and quantum physics, and, eventually, the convergence of nanotechnology, biotechnology, information technology, and cognitive science.

Many of the assumptions that governed our approach to chemicals regulation may no longer hold. Because the risks of nanomaterials are poorly related to mass (and depend on other characteristics like surface area, chemistry, charge, etc.), governments and industry will have to rethink the mass-based approaches that have historically shaped our toxicology, regulations, and regulatory-related monitoring systems. In addition, as nanomaterials become more complex and multi-functional, new properties will emerge that are not predictable from the simple chemical approach of current regulations.

We need a systemic analysis across agency statutes and programs, across agencies, and across the international landscape. This should include existing regulations, voluntary programs, information-based strategies, state and local ordinances, and tort law. All these measures need to be evaluated not just in terms of their applicability to nanotechnology today, but also in terms of their efficacy in 5 or 10 years. We need an oversight blueprint that is proactive, transparent, and, for industry, predictable both now *and into the foreseeable future.*

Lack of Public Engagement

We know from public surveys and polls that the government and industry will have to win the public's trust on nanotechnology. The emergence of viable markets depends on strong and growing consumer confidence.

However, in the midst of nanotechnology's commercialization, publics throughout the world remain largely in the dark. A major study, funded by NSF and conducted in 2004 by researchers at North Carolina State University (NCSU), found that 80–85 percent of the American public has heard "little" or "nothing" about nanotechnology.[14]

This is consistent with similar polling results in Europe and Canada. Anecdotally, some researchers believe that an even higher percentage of the public remains uninformed about nanotechnology. These same citizens are now meeting nanotechnology products in their local store or on the Internet. The public will increasingly have to make sense of competing claims, complex science, and emerging risk research, all with little or no preparation or support. Into this mix enter an increasing number of NGO groups interested in shaping public opinion in various directions, some of which may have large strategic implications for business and government.[15]

In 2005, the Project on Emerging Nanotechnologies commissioned a new report by Senior Associate Jane Macoubrie, who co-authored the North Carolina State University study in 2004. This new report, "Informed Public Perceptions of Nanotechnology and Trust in Government," provides an in-depth look at American attitudes toward nanotechnology.[16]

It indicates that U.S. consumers, when informed about nanotechnology, are eager to know and learn more. They generally are optimistic about nanotechnology's potential contribution to improve quality of life. The key benefits the public hopes for are major medical advances, particularly greatly improved treatment for cancer, Alzheimer's, and diabetes.

The Project's report findings track closely with work done in 2004 by University of East Anglia researcher Nick Pidgeon for Great Britain's Royal Society. Pidgeon also found there were few among the British public who knew much about nanotechnology. Those that did were optimistic that it would make life better.[17] This general public optimism about nanotechnology is what I consider the "good news." This optimism is tempered by a significant amount of suspicion about industry's intentions, and skepticism about the government's commitment to effective oversight.

For policymakers, the "take home" messages that emerge from these studies are quite clear:

- Consumers want more information to make informed choices about nanotechnology's use and greater citizen engagement in shaping how the technology is developed.
- There are low levels of trust in government and industry to manage any risks associated with nanotechnology. There is little support for industry self-regulation or voluntary agreements. A majority of the public believes that mandatory government controls are necessary.
- People have clear ideas about how to improve trust. They want government and industry to practice *due diligence* to ensure manufacturing and product safety. In both U.S. and U.K. studies, this translated into strong support for research and safety testing *before* products go to market and a focus on better understanding long-term effects on both people and the environment.

In my view, there is still time to inform public perceptions about nanotechnology and to ensure that nanotechnology is developed in a way that citizens—as well as the insurance industry, corporate investors, NGO's, and regulatory officials—can trust. However, with the production of nanosubstances ramping up and with more and more nanotech-based products pouring into the marketplace, this window is closing fast.

Worries are already being voiced that public input will now be used simply as a "tokenistic add-on" rather than as a valuable policy-making tool.[18] Coordinated education and engagement programs will be needed, supported by both government and industry. Public engagement programs will have to be structured to reach a wide range of consumers, cutting across age, gender, and socioeconomic status, utilizing a variety of media going beyond traditional print, radio, television and film, and toward non-traditional media such as blogs and multiplayer online games.

Lack of Coordinated Research Strategies

There are currently no coordinated research strategies designed to address the potential environmental, health, and safety risks posed by nanotechnology. In the absence of such a risk-related research strategy, it will be difficult for the public or for small and medium sized companies to learn about the downsides of the technology and reach conclusions about where the greatest risks lie. Additional research about potential workplace hazards, environmental implications, and human health toxicity needs to be done and made readily available to small and medium sized nanotechnology corporations.

Over the past 15 years, scientific data on the health and environmental impacts of nanostructured materials has been growing slowly. However, research on the implications of manufactured nanomaterials has only been available for the past 5 years. Though much of the research undertaken so far has raised more questions than answers, a number of key points have emerged, including:

- Since engineered nanomaterials show behavior that depends on their physical and chemical structure, risk assessment paradigms that have been developed based on traditional, bulk chemistry alone may no longer be valid.
- Inhaled, nanometer-structured, insoluble particles can elicit a greater response in the lungs than their mass would suggest, indicating mechanisms of action that are dependent on particle size, surface area, and surface chemistry, among other properties. However, information is lacking on nanomaterials' structure-related behavior in the body.
- Inhaled, nanometer-diameter particles may leave the lungs through non-conventional routes and affect other parts of the body, including targeting the cardiovascular system, the liver, kidneys, and the brain. Next to nothing is known about the impact of engineered nanomaterials on these organs.
- Nanometer-diameter particles may be able to penetrate through the skin in some cases, although this is still an area of basic research and the chances of penetration appear to be significantly greater for damaged skin. The potential for nanostructured particles present in cosmetics and other skin-based products to do harm may be low, but remains unknown.
- Little information on how manufactured nanomaterials may affect ecosystems and how they might bioaccumulate.
- Virtually nothing is known about the hazard of engineered nanomaterials ingested as a food additive or by accident.

To date, the majority of research on the environmental, health, and safety (EH&S) implications of nanotechnology has focused on relatively basic engineered nanomaterials. As nanomaterials move from simple to complex materials and on to active and multifunctional materials, major knowledge gaps need to be filled before useful

quantitative risk assessments can be carried out and before comprehensive, lifecycle risk management strategies can be developed.

A number of groups have developed, or are in the process of developing, lists of research priority areas and questions of interest. These organizations include EPA, NIOSH,[19] Environmental Defense,[20] the Semiconductor Research Corporation, the Chemical Industry Vision 2020 Technology Partnership,[21] and the Project on Emerging Nanotechnologies. Despite the diversity of these organizations, these gap analyses are generally in broad agreement on the areas requiring further research and development. Common themes include: toxicity (human and environmental), exposure and material release/dispersion, epidemiology, measurement and characterization, control of exposure and emissions, safety hazards, risk management models, and product life cycle analysis.

However, more needs to be done to engage small and medium sized businesses in setting research agendas and outlining where knowledge gaps exist. Without such involvement, EH&S research may not be able to adequately address and provide substantial answers to many risk management questions that will emerge in both the near and long-term future for these companies. Therefore, an effective, forward-looking, internationally accepted, small and medium sized business focused, EH&S research strategy needs to be developed to fill this gap.

Recommendations for Nanotechnology Commercialization

Let me provide three general recommendations to improve the overall climate for commercialization that will help companies, investors, and consumers. The goal is to ensure the benefits overweigh the risks, firms have a clear path to market, and public confidence grows.

- *We need to put our research in front of product flows to both inform oversight and regulatory strategies with good science and to provide important information on risks and benefits to the public.* There has been a surprising consensus between industry, trade associations, think tanks, and environmental NGO's concerning the urgent need for more EH&S research funds and the need to make sure these funds are *strategically* allocated to deal with existing *and* emerging risks. For instance, though we know there are already ingestible nanotechnology products on the market—along with a number of promised applications in the agriculture and food sectors—there is a total lack of research on the impacts of nanomaterials in the gastro-intestinal tract. Given the lag time between the initiation of research and the results, greater efforts need to be made to place research on environmental, health, and safety concerns further "upstream" in the product development process.[22] Such research needs to be coordinated at a global level, since the commerce in nanotechnology materials and products is, and will continue to be, worldwide.
- *For commercialization to succeed, we need an oversight system that is transparent, efficient, and predictable.* We do not have that now. Companies are often confused about the regulatory intentions of the government, investors and insurers are insecure, and the public is suspicious. In his report on the subject, Dr. J. Clarence Davies noted that "nanotechnology is difficult to address using existing regulations," since they "either suffer from major shortcomings of legal authority, or from a gross lack of resources or both."[23] Short of new legislation, which must be seriously considered, there is much more government and industry can do to provide adequate oversight on emerging products. One approach is applying a portfolio-of-initiatives strategy to key product areas.[24] Using cosmetics as an example, one could assemble a portfolio which combines the FDA's Voluntary Cosmetic Registration Program (VCRP),[25] the Cosmetic, Toiletry & Fragrance Association's (CFTA) Cosmetic Ingredient Review (CIR),[26] labeling guidelines, and consumer education efforts by industry and government. Such a multi-faceted system could be used to "fast-track" the review of key nanomaterials, such as carbon fullerenes, that are already being used in high-exposure cosmetic products. Integrating industry, government, and association efforts would help bolster the insufficient level of human resources that exist in the regulatory agencies.[27] Such a portfolio-based approach requires not only integrating initiatives, but a constant evaluation of progress and a willingness on the part of government and industry to make midcourse corrections if necessary.
- *Finally, resources for public engagement need to be increased by orders of magnitude and engagement activities need to be rapidly accelerated.* We have waited far too long to begin engaging the public about nanotechnology. Successful commercialization without strong consumer confidence is impossible. How consumers find out about nanotech, from whom, and with what messages will be

critical to nanotechnology's long-term success. Key impressions will be formed over the next 2 years that will affect consumer confidence far into the future. The "21st Century Nanotechnology Research and Development Act" requires the government ensure that "public input and outreach . . . be integrated into the Program by the convening of regular and ongoing public discussions, through mechanisms such as citizens' panels, consensus conferences, and educational events."[28] However, nothing along these lines has occurred in over a year and a half, and the first meeting on this topic will take place at the end of this May to discuss *how* to do public engagement, not to actually engage the public. The longer we wait, the greater the danger that the public will see such efforts as disingenuous, "after the fact," and tokenistic.[29]

These three steps should be taken together, properly resourced, and integrated. Frankly, with products flowing into the market at an increased rate, we do not have a lot of time. There is no "pause button" for technological innovation that government can conveniently push to create time for research, testing, policy deliberation, or a few more public meetings. By the time we have settled on nomenclature for the first generation of nanomaterials, the next generation will be upon us; by the time we have characterized risks of early nano-based substances, newer, more complex materials will be on the market. Without better foresight, our answers will be for yesterday's questions.

Focused Recommendations

In addition to creating a more strategic and forward-looking approach to research, oversight, and public engagement, there are also a number of more focused activities that can be undertaken to accelerate the commercialization of nanotechnologies.

First, our commercialization policies and programs need to be informed by rigorous data about nanotech firms, their products, their issues, and needs. We have virtually no government-derived data to guide commercialization strategies, a situation that is dangerous given our multi-billion dollar investments in nanotechnology. The Department of Commerce should work to collect and continually update survey data on nano businesses, especially startups, working, as needed, with the Bureau of Labor Statistics, the Census Bureau, or other data collection arms of the U.S. Government. As with other sectors and industries, data should be collected on demographic characteristics of the labor force, R&D expenditures, revenues, environment/health/safety issues, injuries/illnesses, exports, and the geographic profile of the firms. We should also better understand who could best help these firms with which issues. Will they access websites, use technical assistance programs at nearby universities, or prefer peer-to-peer mentoring from other firms? The Project on Emerging Nanotechnologies is presently working with Yale University and the University of Massachusetts at Lowell to survey the environmental, health and safety concerns/needs of nano startups in the New England area, but data collection of this type should be undertaken broadly by the government and conducted over long periods of time as firms change and mature.[30]

Second, we should create a one-stop-shop at a Federal level focused on helping firms with issues around commercialization—an Interagency Nano-Business Office—INBO, where companies in need of help can be quickly directed to the appropriate Federal programs. The existing National Nanotechnology Coordinating Office (NNCO) was set up to coordinate science, not to drive innovation to market and deal with commercialization challenges. Its function needs to be complemented and expanded. The creation of various Nanoscience to Commercialization Institutes around the country does not mitigate the need for a centralized locus in the Federal Government. INBO needs to be structured and staffed to work well with the business and investor communities, and will need the capability to deal with international business issues involving trade, export and intellectual property protection.

Third, we should use the purchasing power of the government, or quasi-governmental organizations, to help create early markets for critical nanotech-based products, especially in the energy sector. The Federal Government purchases approximately 2 percent of all things sold in the United States, with state and local governments purchasing an additional 5 percent. Key players in terms of procurement are the Postal Service, General Services Administration, Department of Defense, and Department of Homeland Security as well as state and municipal agencies with significant buying power. Large procurements can increase economies of scale and prove critical in reducing costs for early stage technologies. The Postal Service cut the per unit cost of energy-saving LED exit signs almost in half by committing to purchase 15,000 units, a change which saved them more than $300,000 per year in energy and maintenance costs.[31] In the energy sector, key nano-based technologies that could benefit from early adoption strategies by government are: batteries, photovoltaics, fuel cells, and lighting.

Fourth, the United States should become the world leader in the development and commercialization of environmentally benign, "green" nanotechnology production processes and products as well as a new generation of nano-based environmental technologies. At the beginning of what may be another industrial revolution, we have a unique window of opportunity to engineer significant risks out of products and processes. Instead, we are creating a long-term employment program for risk assessors and toxicologists. In terms of research funding, we have set up a false dichotomy between applications and implications research, often creating a zero-sum game where we must chose between eliminating or preventing risks or studying them, after the fact. There are already examples that new nano production processes can be both environmentally beneficial and cost effective. For instance, ongoing research at the University of Oregon is being directed at the cleaner and greener production of gold nanoparticles, a process that also reduces the cost of synthesizing these materials from $300,000 per gram to $500 per gram.[32] Though there are over 100 projects being funded by the National Science Foundation that are focused, at some level, on the "green" application of nanotechnology to the environment, more work needs to be done in this area and U.S. leadership established as a means of creating a global niche for our firms and expertise.

Finally, we need to begin developing an export promotion strategy to help U.S. nanotech firms in what will be a tough and highly competitive global market. NSF predicts that the world market for goods and services using nanotechnologies will grow to $1 trillion by 2015. Lux Research calculates that in 2004 there was $13 billion worth of products in the global marketplace incorporating nanotechnology.[33] Worldwide about $9 billion annually is being spent by governments and the private sector on nanotechnology research and development. The thin film and photovoltaic sector is projected to be "worth over $2.3 billion in the year 2011,"[34] and the use of silver nanoparticles in fields as diverse as food packaging and medical devices is "emerging as one of the fastest growing product categories in the nanotechnology industry."[35] This means engaging agencies that have been largely on the sidelines of the National Nanotechnology Initiative but that will play increasingly important roles in commercialization, including the Export-Import Bank, Federal Trade Administration, Trade and Development Agency, State Department, and Small Business Administration. These agencies will be key players in a coordinated export promotion strategy.

There is one important caveat that applies to everything I have mentioned. Any government program, policy, or strategy must work for our small businesses; they are the heart of the nanotech revolution and will remain so into the foreseeable future. According to the 2003 Census, nearly 72 percent of 300,000 manufacturing entities in the United States have less than 20 employees and 92 percent of manufacturing companies have less than 100 employees.[36] Additionally, the Small Business Administration estimates that there were approximately 22.9 million small businesses in the U.S. in 2002 and that small businesses provide approximately 75 percent of the net new jobs added to the economy, represent 99.7 percent of all employers, and represent 97 percent of all U.S. exporters.[37]

In closing, let me say that I applaud the Committee for focusing our attention on issues of commercialization. Nanotechnology is no longer just a large government science research project. In the long run, key social and economic benefits will only occur if we succeed in bringing innovations to market. To do that, we need to place new people, resources, and ideas behind an expanded national nanotechnology initiative.

ENDNOTES

[1] M.C. Roco, R.S. Williams and P. Alivisatos. Nanotechnology Research Directions: IWGN Workshop Report. Berlin, Germany: Springer, 2000, p. iii–iv.

[2] See *http://www.nanotechproject.or/consumerproducts* and Rick Weiss, "For Now, Nanotechnology Means Little More Than Better Golf Balls," *The Washington Post,* March 10, 2006.

[3] "2006 Nanomedicine, Device & Diagnostics Report." *NanoBiotech News*. Atlanta, GA: National Health Information, LLC, 2006.

[4] "Nanotechnology White Paper," Washington, D.C.: United States Environmental Protection Agency, December 2, 2005. Available at *http://www.epa.gov/osa/pdfs/EPA__nanotechnology__white__paper__external__review__draft__12–02–2005.pdf.*

[5] Applying a definition commonly used by the Small Business Administration that a small business has fewer than 500 employees.

[6] Countries include: United States, Mexico, United Kingdom, France, Germany, Switzerland, Finland, Sweden, China, Korea, Japan, Taiwan, Australia, New Zealand, and Israel.

[7] David Graber and Pat Phibbs. "German Institute Working to Understand Why 'Magic Nano' Cleaner Caused Ailments." *Daily Environmental Report,* April 12, 2006.

[8] "Cause of intoxications with nano spray not yet fully elucidated," Berlin, Germany: Federal Institute for Risk Assessment, April 12, 2006. Available at *http://www.bfr.bund.de/cms5w/sixcms/detail.php/7750.*

[9] "Nano Poison Scandal: Misuse of a Major German Testing 'Seal of Approval,'" Berlin, Germany, Federation of German Consumer Organisations, April 14, 2006. Available at *http://www.vzbv.de/go/dokumente/502/4/17/index.html.*

[10] See *http://www.ul.com/media/newsrel/nr031406.html.*

[11] See *http://www.ul.com/media/newsrel/nr030106.html.*

[12] See *http://www.ul.com/media/newsrel/nr040606.html.*

[13] *Nanoscience and nanotechnologies: opportunities and uncertainties.* London, U.K.: The Royal Society and Royal Academy of Engineering, July 2004. Available at *http://www.nanotec.org.U.K./finalReport.htm.*

[14] Michael D. Cobb and Jane Macoubrie. "Public Perceptions about Nanotechnology: Risk, Benefits and Trust." Raleigh, NC: North Carolina State University, 2004. Available at *http://www2.chass.ncsu.edu/cobb/me/past%20articles%20and%20working%20papers/Public%20Perceptions%20about%20Nanotechnology%20-%20Risks,%20Benefits%20and%20Trust.pdf.*

[15] Since 1990, more than 100,000 new citizens' groups have been established around the world. Trust in many of these groups has increased in direct proportion to decreasing confidence in government and industry. See: Bonini, S. M. et al (2006). "When Social Issues Become Strategic," *McKinsey Quarterly,* Number 2.

[16] Jane Macoubrie. *Informed Public Perceptions of Nanotechnology and Trust in Government.* Washington, D.C.: Woodrow Wilson International Center for Scholars, 2005. Available at *http://www.wilsoncenter.org/news/docs/macoubriereport1.pdf.*

[17] *Nanotechnology: Views of the General Public.* London, U.K.: BMRB Social Research, January 2004, BMRB/45/1001–666. Available at *www.nanotec.org.U.K./Market%20Research.pdf.*

[18] Anna Saleh. "Critics say nanotech plan sidelines public," *ABC Science Online,* April 28, 2006. Available at *http://www.abc.net.au/science/news/health/HealthRepublish_1625988.htm.*

[19] National Institute for Occupational Safety and Health. *Strategic Plan for NIOSH Nanotechnology Research: Filling the Knowledge Gaps.* September 28, 2005. Available at *http://www.cdc.gov/niosh/topics/nanotech/strat_planINTRO.html.*

[20] Richard A. Denison. "A proposal to increase Federal funding of nanotechnology risk research to at least $100 million annually." Washington, D.C.: Environmental Defense, April 2005. Available at *http://www.environmentaldefense.org/documents/4442_100milquestionl.pdf.*

[21] Semiconductor Research Corporation and Chemical Industry Vision 2020 Technology Partnership. "Joint NNI-ChI CBAN and SRC CWG5 Nanotechnology Research Needs Recommendations."

[22] Recently, our project finished the first phase of a study with the University of Minnesota, in which we analyzed over 150 research projects where nanotechnologies were being developed for food and agricultural applications. This study allowed information to be generated on what products might reach the market first, which oversight mechanisms would be triggered, who might be exposed to risks, etc. See: *http://www.nanotechproject.org/50/live-webcast-agrifood-nanotechnology-reserach-and-development.*

[23] J. Clarence Davies. *Managing the Effects of Nanotechnology.** Washington, D.C.: Project on Emerging Nanotechnologies, Woodrow Wilson International Center for Scholars, 2006.

[24] The use of a portfolio-of-initiatives approach is often recommended as a strategy for dealing with uncertainty. See: Bryan, Lowell (2002). "Just-in-time Strategy for a Turbulent World," *McKinsey Quarterly,* Special Edition, or Courtney, Hugh (2001): *20/20 Foresight: Crafting Strategy in an Uncertain World,* Harvard Business School Press.

[25] See *http://www.cfsan.fda.gov/~dms/cos-regn.html.*

[26] See *http://www.cir-safety.org.*

[27] Though the Federal Government has continually maintained that it has sufficient statutory authority to deal with nanotechnology, it has said nothing about the resources needed to back up existing statutes, which are as critical to success as the statues themselves.

[28] "21st Century Nanotechnology Research and Development Act," S. 189, Washington, D.C.: U.S. Congress, 2003.

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*A copy of the information referred to has been retained in Committee files.

[29] This problem occurred in the U.K. after the government launched a project on public engagement around genetically-modified food (GM Nation), after such products were already on the market.

[30] Another model for this is the Sloan Foundation's Industry Studies Program, started in 1990, which is based on rigorous, observation-based research in firms. See: *http://www.industry.sloan.org/*.

[31] David Rejeski. "An Incomplete Picture," *The Environmental Forum,* September/October, 1997.

[32] Stephen K. Ritter. "Planning Nanotech from the Ground Up." *Chemical and Engineering News,* April 17, 2006.

[33] "Sizing Nanotechnology's Value Chain." New York, NY: Lux Research, October 2004.

[34] *http://www.electronics.ca/PressCenter/articles/274/1/Thin-Film-And-Organic-Photovoltaic-Market-To-Reach-%242.3-Billion-%28%24US%29-In-2011.*

[35] See *http://www.electronics.ca/PressCenter/articles/292/1/Use-Of-Silver-Nanoparticles-Rapidly-Expanding-In-The-Consumer-And-Medical-Markets.*

[36] See *http://www.sba.gov/advo/research/data.html#us.*

[37] "Small Business Statistics." Washington, D.C.: Small Business Administration. Available at *http://www.sba.gov/aboutsba/sbastats.html.*

Senator SMITH. Thank you very much, David. Those are some very good suggestions, and I've got some good staff here that's jotted them all down, and we'll see if we can't get them into the bill, or another bill that we will produce. Obviously, we don't want any more government than is necessary, but having some data and some regulations to keep it safe and keep the confidence of consumers up, is very important.

Do you know enough about the Magic Nano? Has that created sort of a biofoods sort of backlash?

Mr. REJESKI. I don't think so. I mean, I think—the good news is that the German Government and the Europeans responded very quickly. They have very effective early warning systems. All of these cases were reported immediately by doctors who saw the patients. But I think it tells us some of the problems. I think, in the end, the public is not going to sort through the science here.

Senator SMITH. Yes.

Mr. REJESKI. What they're going to remember is "nano," and "nano" is associated with adverse health outcomes. And I think that's something that we want to avoid. I think, also, the case has dragged out right now. It's been actually elevated to an EU level, because there's issues about, What was it in this product that caused the problems? And some of the ingredients now come from Luxembourg. The longer it stays in the press, the worse off we are, I think. So, it was unfortunate, but—and the other thing which I think is quite serious is the misuse of a label like——

Senator SMITH. Yes.

Mr. REJESKI.—like a UL label.

Senator SMITH. Right.

Mr. REJESKI. One of the things the public has told us in a lot of the focus groups that we've done is, one way to really increase trust in government and industry around nano is more disclosure and transparency, and third-party independent testing.

Senator SMITH. Yes.

Mr. REJESKI. And so, if the public loses trust in independent testing organizations, I think we're in real trouble.

So, I think you have to stay tuned. I'm hoping that it'll resolve quickly, but it's going to be a test of the system.

Senator SMITH. Yes.

Mr. REJESKI. And there was a bunch of things that happened simultaneously, essentially—the labeling, the inability to find out what's going on, the lack of disclosure. I think all of that really undercuts public confidence.

Senator SMITH. Yes.

Mr. REJESKI. We want public confidence to go this way——

Senator SMITH. Yes.

Mr. REJESKI.—as we introduce products into the marketplace.

Senator SMITH. I know, it's biogenetically modified foods have been sort of a disaster in Europe, but, I'm not sure it was based on science, but it certainly was based on perception and——

Mr. REJESKI. Right.

Senator SMITH.—and advertising. I don't want nano to go the same way.

Mr. REJESKI. Well, you know, it's interesting, because I was thinking about just local government. I mean, certainly you remember what happened in the early 1970s with recombinant DNA.

Senator SMITH. Yes.

Mr. REJESKI. Incredible fears we were going to release these pathogens, they were going to cause major damage. The scientists were afraid. We knew virtually nothing about the risks. At that point in time, there was one community, Cambridge, Massachusetts, that stepped forth in 1976 and put in place the first biotech ordinance. They actually said, "In a sea of ambiguity, we're going to create some clarity." They set up a Citizen Review Panel. They set up fairly strict oversight and the ability of people to get in and work with the firms to make sure they were operating on a safe level.

What happened was, firms moved to Cambridge. In fact, in 1980, Biogen, which is a huge Swiss biotech company, moved into Cambridge, and they asked Biogen, "Are you crazy?" essentially moving into the most regulated area in the world. And they said, "That's exactly the point. We know the oversight. We trust it. And, most importantly, the community trusts the system." And, the rest is history. Cambridge has become an oasis for biotech innovation. There's over 50 biotech firms there. After 30 years, they still have the ordinance in place. It's still working.

Senator SMITH. Wow.

Mr. REJESKI. We talk a lot about what can happen in the Federal level, but there's an awful lot that could be done, I think, to increase consumer confidence. It's that—a lot of companies and investors I talk to want—they want a system that's predictable. It's not that they're against regulation; they don't want ineffective regulation, but they want something that actually—they understand——

Senator SMITH. No, regulation can be helpful to commercialization.

Mr. REJESKI. Yes.

But it's a fascinating story. And it always reminds me, when I hear what's happening in a small community like this, that even communities can step forth and, I think, create this——

Senator SMITH. Are these products you have in front of you currently on the market?

Mr. REJESKI. They're all on the market. This is a new one we just got. This is actually Tupperware that has nanosilver in it. It's

antimicrobial. There's a number of sunscreens here. These are dietary supplements. I don't know if you're a golfer, but this—this hasn't helped my game, but——

Senator SMITH. Yes.

[Laughter.]

Mr. REJESKI.—people swear by it. I guess if you're Tiger Woods, you get something from this. Lip balms. We've shared these with FDA, and most scientists know if you don't know a lot about the risks, you really want to try to limit exposure. And a lot of these products are being ingested or put on your skin, so I think that there are areas where we need to look closely at the oversight system. There's a tendency to talk about nano in terms of cures for cancer and the space elevator. These are all amazing kinds of innovations. But this is the face right now. This is what the consumers are seeing. And I want to make sure that we get over the next 2 years without any kinds of speedbumps.

Senator SMITH. Well, thank you all, gentlemen, so very much.

Sean, you look like you want to say something.

Mr. MURDOCK. I just wanted to say, again, we appreciate your holding this hearing. Nanotechnology has profound opportunities to change the world around us, but not just in abstract ways, to reinvigorate the economy. You know, I, as Chairman Stevens pointed out, come from Illinois, and Illinois has certainly had its set of issues in the manufacturing economy. And I think it's—that it's important that we keep our eye on the ball and how this is going to affect the folks around us and lead to better, higher-paying jobs. And this kind of activity that we're talking about with the legislation that you've introduced, I think, is a meaningful step in the right direction.

Senator SMITH. Well, I would just simply conclude by saying that Congress's role is to hold hearings and flesh out good ideas, and turn them into laws, and then, where necessary, to bring light and heat to an issue to get it to advance. And that's been the purpose of today's hearing, to push along the practical application of this part of science to improve the life of the American people. And so, you've all contributed mightily, and each in his own segment, add to that public record. And so, we're very grateful for your time. I apologize again. The voting schedule of the Senate had us delayed a bit. But we've gotten through it, and it has been worthwhile, to me, and I hope to others, as well.

Well, thank you.

With that, we're adjourned.

[Whereupon, at 4:28 p.m., the hearing was adjourned.]

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